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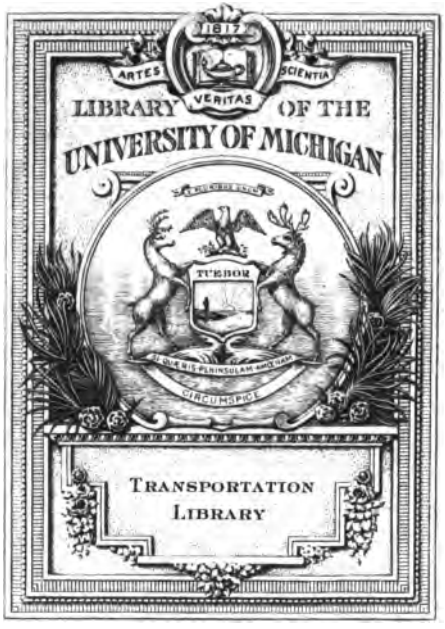


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# TRANSPORTATION BY RAIL:

## AN ANALYSIS

OF THE

## MAINTENANCE AND OPERATION OF RAILROADS,

SHOWING THE CHARACTER AND COST OF THE SERVICE PERFORMED BY RAILWAY COMPANIES IN THE MAINTENANCE OF HIGHWAYS FOR COMMERCE, AND AS COMMON CARRIERS OF PASSENGERS, FREIGHT, AND THE UNITED STATES MAILS OVER SUCH HIGHWAYS.

BY

T. M. R. TALCOTT, C. E.

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# PREFACE.

THIS monograph is based on the experience of the writer in the construction, maintenance and operation of railways for many years, during a large part of which he had the accounts kept to suit his special method of analyzing the cost of maintenance and operation.

The present method of accounting, as established by the Interstate Commerce Commission, does not admit of the application of this method of analyzing operating expenses, and therefore the present cost of the several units of service cannot be accurately stated; but general managers who wish to know the exact cost of each unit of service on their roads can no doubt have their accounts kept so as to admit of the application of the method of analysis indicated in the following pages.

This method of analysis was applied to a number of Southern roads for periods of from three to ten years, and the units of cost ascertained naturally differed somewhat for the same service, owing to different conditions on the different roads, such as different standards of construction and equipment, varying rates of pay for the service of similar classes of employees, and diversity in the cost of material and supplies during different periods and in different localities, but the variations in cost per unit of service were within comparatively narrow limits. The road, of which statistics are given in the following pages, was selected for illustration because it seemed to fairly represent the general average of Southern roads, which had been in operation a number of years, and were of the same general standard of construction and equipment.

If this book stimulates investigation of the economic questions to which it directs attention, the writer will not have labored in vain.

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# TRANSPORTATION BY RAIL.

## CHAPTER I.

### Changes in Physical Conditions and Methods of Operating Railways.

THE first railroads were more of a novelty in transportation than a means of cheapening its cost. The superstructure of some of the earlier ones was made by placing thin flat bars of iron on longitudinal timbers, which rested on stone blocks bedded on broken stone ballast to prevent their displacement by frost. In some cases the iron bars were supported by continuous stone sills. Subsequently iron bars of greater thickness were used, and then the H-rail, of fifty pounds per linear yard, resting on longitudinal sills, the weight of the rails being gradually increased to sixty, seventy and seventy-five pounds per yard. Then cross-ties were introduced, resting on longitudinal sills, and finally the sills were removed, and gravel ballast substituted for them.

The first cars used were coach bodies of the ordinary form, placed on frames with four wheels, but they were gradually enlarged, and the form changed until their capacity was increased to sixty passengers, two trucks being used with each car body which could adjust themselves to the curves in the track.

The first locomotive engines weighed only six tons; but they were successively increased in weight to ten, sixteen, twenty and twenty-six tons, and on some of the "freighting roads" locomotive engines of forty tons were used as early as 1854.

An official investigation made about that time to determine the cost of transporting passengers and freight by rail resulted in what would seem now to be an absurd conclusion, that the cost of transporting a passenger or a ton of freight one mile was the same; but it was probably not far wrong then, for at that time the average number of passengers and the average number of tons of freight per train was very nearly the same, and there was little, if any, difference in the gross weight of passenger and freight trains. Since that time the average number of passengers per train has decreased, and the average number of tons of freight per train has increased, making the gross load per passenger much greater, and the

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gross load per ton of freight much less, than it was formerly. As an instance of this, it may be stated that in 1854 the average train loads in the State of New York were:

Passenger trains, ....68 passengers. Freight trains, ....69 tons.

While, according to the Interstate Commerce report, the average train loads for Group 11, which includes the State of New York, in 1898 were:

Passenger trains, ....43 passengers. Freight trains, ....282 tons.

The requirements of the passenger service have tended to increase the frequency of trains, as well as their speed, with more elaborate provision for the safety, ease and comfort of passengers, resulting in more dead weight per passenger mile; while, on the other hand, the tendency of the freight service has been in the direction of heavier train loads, and less dead weight in proportion to paying loads.

Whilst competition has been a controlling influence in the development of facilities for the modern passenger service, and has compelled attention to economic methods in the transportation of freight, the improvements in the freight service have resulted largely from broad-minded and intelligent efforts to make possible the handling of products which were formerly not worth the cost of transporting them to market by rail.

One of the earliest attempts to ascertain the cost of transportation by rail was on a coal road in Pennsylvania, and resulted in showing that heavy mineral traffic could be handled at about one cent per ton per mile. This was probably the first illustration of the effect of a large volume of traffic and heavy train loads on the cost of transportation.

In order to appreciate the methods by which the cost of railway transportation has been so greatly reduced that canals are almost out of date, and the great river routes are successfully paralleled by rail lines, it will be necessary to understand the several kinds of service involved in the maintenance and operation of a modern railway, and their relations to the cost of transportation.

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## CHAPTER II.

### Diversity of Service Rendered to the Public and Methods of Reducing its Cost.

### The Highway.

THE most obvious diversity of service performed by a railway is found in the fact that it not only maintains a highway over which persons and property are transported, but also furnishes the means of transportation over such highways, thereby performing the service of both a common carrier and warehouseman.

The highway is separate and distinct from the transportation service, and, with the exception of the abrasion of the rails, frogs and switches, its maintenance is practically the same, whether the traffic done over it is much or little. The maintenance of the roadbed structures and cross-ties which support the rails may cost more or less, according to the standard of excellence adopted in constructing the highway, but whatever the cost may be, it will be practically a fixed expense.

### Terminal and Station Service.

The transportation of passengers and freight over the highway is not a single operation, for it is necessary to make provision for receiving and ticketing passengers, handling and checking their baggage, and for receiving, loading, manifesting, switching, unloading and delivering freight, in addition to hauling them from initial point to destination. This terminal or station service is about the same for each passenger or for each ton of freight, whether they are hauled a long or a short distance, and its cost depends upon the number of passengers or the number of tons of freight, and not upon the distance travelled by passengers, or the distance freight is hauled.

### Transportation Service.

The hauling of passengers and freight after they are in the cars is an additional service, represented by the number of miles travelled by passengers and the ton miles of freight hauled; but the cost is not directly in proportion to the

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aggregate number of passenger miles or the ton miles of freight. One reason for this is that a large proportion of the work done is in the transportation of "dead load," or the cars which carry the passengers and freight. The dead and paying load together represent the work done, and not the paying load only, and consequently the gross ton mileage is an important factor in the cost of transportation. It may be stated here, however, that while the number of gross ton miles resulting from the movement of trains represents the work done in weight and distance, the cost of transportation is not necessarily in proportion thereto, for the power required depends not only upon the gross weight of the trains and the distance, which is expressed in gross ton miles, but also on the resistance due to gravity in ascending grades, the resistance due to speed, and the resistance due to curvature.

The power required to haul one gross ton one mile depends, primarily, upon the alignment and grades of the road; but the proportion of paying load included in the gross ton mileage depends largely upon the intelligence and skill of the operating department in dispensing with unnecessary car mileage, which is always the surest economy.

The great reduction which has been made in the cost of transportation, whereby the railway companies have been able to meet competition and enlarge their usefulness in the development of trade, is accounted for as follows:

*First.* Reductions in grades and curvature, stronger bridges, heavy rails and more perfect alignment and surface of track have not only reduced train resistances, but made practicable the use of heavier locomotives, and have increased the carrying capacity of the railways without a corresponding increase in train mileage.

*Second.* Increased volume of traffic has reduced the cost of transportation per passenger and per ton of freight per mile by reason of the fact that a considerable part of the cost of operating railways is the same whether the traffic is great or small.

*Third.* Heavier trains have reduced the cost of transportation, because the more cars there are in one train the less it costs to haul each car, which is due to the fact that a considerable part of the cost of running trains is the same whether the trains are heavy or light.

*Fourth.* Increased loading of cars has reduced the cost of transportation, because it increased the proportion of paying load included in the total weight of

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trains, and the total weight or gross tonnage determines a considerable proportion of the transportation service and its cost.

These are the general principles on which the cost of transportation by rail has been reduced during the past fifty years, and on which further reductions may yet be effected.

It is unfortunate that it has not been the custom of all railway companies to keep an accurate account of their gross tonnage, as well as of their train mileage and car mileage. The work done by locomotives is generally shown on the "locomotive performance" sheets by the number of loaded cars hauled, counting two empties as equivalent to one loaded car, which has been found so unsatisfactory that a strong effort is being made to have the ton mile, or gross tonnage, basis generally adopted. Hereafter we may have accurate statements of gross tonnage, but now we can only estimate it from the engine and car mileage and the statistics of traffic reported, except for a few roads, which have heretofore appreciated the value of such information as a means of ascertaining the actual work done by locomotives in hauling passengers and freight.

Another difficulty arises from the fact that in operating railways, as in other business dependent upon the patronage of the public, it is often deemed necessary or advisable to make more or less liberal expenditures for extras that contribute nothing to the efficiency of the service rendered, and cannot be considered an essential part of cost of operation, but rather as accessories to please patrons. However much we may admire parterres of flowers at a railway station, we cannot regard the cost of them as a necessary part of the station expenses; but it is not so easy to discriminate in all cases between essentials and mere accessories to the transportation service.

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## CHAPTER III.

### Relations of Different Kinds of Service Rendered to the Cost of Transportation by Rail.

IT has been shown in the preceding chapter that the railway has assumed the functions of three of its predecessors, in that it not only maintains a highway for commerce, but also performs the duties of both the warehouseman and the common carrier; but we have not yet carried the analysis far enough to see the complexity of its operations in detail.

#### Administration.

To conduct any business intelligently, with efficiency and proper economy there must be proper supervision and direction by competently trained managers, who do not necessarily participate in the actual work done, but are, nevertheless, an essential part of the organization and important factors in the results to be attained. The general officers and heads of departments perform these functions on a railway which may be termed the "administration" of its affairs. Administration being neither a part of nor proportionate to the "transportation service," the necessary cost of it may properly be considered a fixed expense proportionate to the length of the road, and the number of its tracks.

#### Maintenance of Roadway, Structures and Buildings.

After establishing the highway over which the transportation service is to be performed, and making provision at convenient intervals for the receipt and delivery of passengers and freight, the substructure for the track, which includes the roadbed, bridges, culverts, cattle-guards, road-crossings, ballast and cross-ties, and also the station building, houses for employees, signals, mile-posts, etc., must be kept in repair and renewed. These repairs and renewals are included in the "maintenance of roadway, structures and buildings," the cost of which, including premiums paid for fire insurance, may properly be considered a fixed expense proportionate to the length of the road, but will be more or less per mile according to the number of tracks and character of construction.

The deterioration of rails, frogs and switches results in part, no doubt, from

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natural causes, and they would not last forever, even if no trains passed over them. It has been said that rails show the greatest abrasion where they are subjected to the most frequent alternations of moisture and dryness, and there can be no question that near the seacoast exposure to the salt air produces rapid oxidation of iron and steel. Nevertheless, the deterioration of rails is practically due to abrasion from the wheels of locomotives and cars passing over them. The better the alignment and surface the less the abrasion will be, but every ton of engines, cars and loads makes its impression on the rails, frogs and switches, and, therefore, it necessarily follows that their deterioration is proportionate to the gross ton mileage more nearly than to the train mileage or the car mileage.

## Taxes.

In the statements required by the Interstate Commerce Commission taxes are made a deduction from income, and they may with equal propriety be considered a part of the "fixed charges" to be paid out of income, but they may also be treated as fixed expenses proportionate to the length of the road, and number of tracks.

## Terminal and Station Service.

Terminal and station service includes the work which necessarily precedes the transportation of passengers and freight, and also that which follows and completes the service rendered in transporting them, but this service is not the same for every passenger or for every ton of freight. Competition for through traffic makes it necessary to maintain outside agencies which are distinct from the local agencies, and it is advisable to separate the two, for which reason I subdivide the terminal and station service into two classes: "Ordinary," to include service rendered at terminal points and intermediate stations, and "Special," to include all outside agencies.

Such part of this service as pertains to passengers will be regulated by the number of passengers provided for, and such part of it as pertains to freight by the number of tons of freight handled. The cost, therefore, should be nearly proportionate to the number of passengers provided for, and the number of tons of freight handled, without regard to the distance the passengers and the freight may be hauled.

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### Transportation Service.

The movement of passengers and freight is effected by means of trains composed of a locomotive engine, which furnishes the necessary motive power and cars for passengers, mail and express, or for freight traffic. Only one locomotive engine is absolutely necessary to the make-up of a train, but the number of cars in one train is limited only by the capacity of the engine to haul more or less; and each car hauled constitutes a separate unit of service. This fact alone would require us to regard the running of trains as a dual operation, but we must further consider that in order to run trains properly there must be a train crew for each train in addition to the engine crew, and that each train must be equipped with signals and necessary supplies.

It is customary to pay the engine and train crews for the number of miles they run, measuring their service by the train mileage; and the train supplies used are generally proportionate to the train mileage, but repairs of engines, stores, fuel and water are more nearly proportionate to the gross ton mileage than to either train or car mileage. The maintenance of home cars, hire of foreign cars, and supplies used in operating them, are proportionate to the use made of them, or to car mileage.

For the reasons above stated, we cannot consider the transportation service a single operation, the cost of which is proportionate to either the train mileage or car mileage; nor is it dependent wholly upon the gross ton mileage. It includes three classes of service in varying proportions, viz.:

Train mileage,
Car mileage,
Gross ton mileage.

The different kinds of transportation required of railways make it necessary for them to run trains of different classes of cars, and cars of different classes in the same train, which still further differentiates the transportation service into two classes:

Passenger train service.
Freight train service.

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Both classes of trains use the same highway, are run under the same general administration, and contribute to the expenses of conducting transportation and the cost of maintenance of equipment. It is necessary, therefore, for a proper understanding of the relative service performed by these two different classes of trains, that accounts should be kept of the train miles, car miles and gross ton miles of each, so that the cost of the different kinds of transportation service may be ascertained as nearly as practicable, for without at least approximate knowledge of what each class of service costs there can be no intelligent understanding of the results of operation.

On roads of light traffic it is customary to combine the passenger and freight service, making a mixed train of cars, and it is also not unusual to allow a few passengers to travel on freight trains without proper cars for their accommodation; but the trains are, nevertheless, freight trains, though entitled to a credit for such reasonable proportion of the cost of running them as may be fairly chargeable to passenger train service.

Recapitulating the foregoing, we have different kinds of service classified in relation to conditions which influence their cost, as follows:

*First.* Service the cost of which is not materially influenced, if at all, by the volume of the traffic or the distance it is hauled, viz.:

Administration.
Maintenance of Roadway, Structures and Buildings.

*Second.* Service the cost of which depends upon the volume of the traffic, but not upon the distance it is hauled, viz.:

Terminal and Station Expenses—Passenger.
Terminal and Station Expenses—Freight.

*Third.* Service the cost of which depends on both the volume of the traffic and the distance it is hauled, viz.:

Train Mileage—Passenger.
Train Mileage—Freight.
Car Mileage—Passenger.
Car Mileage—Freight.
Gross Ton Mileage—Passenger.
Gross Ton Mileage—Freight.

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## CHAPTER IV.

### Cost of the Different Classes of Service which are Included in the Maintenance and Operation of Railways.

BOOK-KEEPING may be simple or complex, according to the information it is desired to obtain therefrom, and the primary object in keeping the accounts of a corporation is no doubt to show the amount of money received and the proper application of what is paid out; but both individuals and corporations want to know more than this, and the best method of keeping accounts is that which will at any and all times give the operator such thorough and practical knowledge of the details of his operations as will enable him to manage his business intelligently.

It may not be practicable to determine the exact source of every dollar of income, or to charge every dollar of expense to the particular transaction which made the expenditure of such dollar necessary, or precisely the net results of each transaction, but the nearer the accounts approximate to such a showing the better the operator will understand the result of what he has done, and the more intelligently he can conduct his subsequent operations.

The more frequently and the more accurately comparisons can be made of expenses incurred in similar operations, the better they will be understood, and the more intelligent will be the efforts for better results; but much time and labor can be saved by grouping together such expenses as result from similar operations, service or transactions, and comparing them in the aggregate, instead of in detail. This is the object of the groupings made of the expenses incurred in operating railways, and it would be most convenient and satisfactory if there was always a definite relation between each group of expenses and certain operations from which they result.

To determine whether an increase in certain expenses is reasonable and proper, we must know whether there was a proportional increase in the work, and to ascertain this, we must be able to compare the work done in each case by some definite unit, such as a train mile, a car mile or a gross ton mile. Hence, the importance of keeping account of the units of service and separating the expenses resulting from each class of work done in operating railways, if only to facilitate comparisons.

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While it is of great importance that a railway manager should know what the comparative cost of maintenance and operation has been, such comparisons will not be useful in determining how to secure better results in the future unless they show how the service can be better adjusted to the requirements of the traffic to save unnecessary work. The lessons of the past are useful only to the extent that the information acquired can be used to influence future results. It is not enough to know that the total operating expenses are out of proportion to the total earnings, for it may be that the profits in one class of traffic are neutralized by losses on another class. Passenger business may be done at a loss that will absorb all or a large part of the profits of freight traffic, and part of the freight traffic may be done at a loss, and detract from the profits of the remainder. There is a strong and abiding impression in some quarters that railway companies charge high rates on local freight traffic to make up for losses on competitive traffic; and how are we to say that such is not the case if we do not know the cost of doing either local or competitive business? Railways will never be able to make proper defence against this and other charges until they can show with some degree of accuracy what each and every class of business does cost them.

We have already considered the relations of the different kinds of service performed by railways to the cost of transportation, but the actual cost of each class of service is what each railway company ought, if possible, to know, and I will endeavor to show how it can be ascertained with sufficient accuracy for all practical purposes, if accounts are kept with that object in view.

### Fixed Expenses.

It is evident that if a road were operated for passenger traffic alone, all of the fixed expenses would be chargeable to the passenger traffic, and if for freight traffic alone, they would in like manner be all chargeable to the freight traffic; but as there are several kinds of traffic on the same road, the fixed expenses must be distributed equitably amongst them.

If a railway were maintained as an open highway, to be used alike by the trains of any common carrier, tolls would be charged, as on a turnpike or canal, and the assessment of the different classes of traffic to cover the fixed expenses may therefore be made on any fair basis of tolls. It has been customary with railways to distribute these expenses in proportion to the mileage of passenger and

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freight trains, which seemed reasonable when there was little difference in the weight of such trains, but the disproportion is now so great that some other and more equitable basis must be found.

The relative use of the highway for each class of traffic must be determined by some common unit of measure; but neither the train mileage nor the car mileage will fairly represent the relative amount of the different kinds of transportation for which the highway is used. The gross ton mile would seem to be the only common unit of measure for all classes of traffic, and, therefore, the distribution of fixed expenses between the several classes of traffic should be made on the basis of their relative gross ton mileage.

### Terminal and Station Expenses.

The terminal and station expenses are to a great extent incurred for either passenger or freight business, and not for both together, and to that extent they can be charged directly to one or the other class of service, and such as are for purposes in common can always be apportioned on some equitable basis.

### Train Expenses.

There is no difficulty in keeping the expenses of each class of trains separate, and it should always be done, as there is a material difference in their cost per mile run. They include motive power (except fuel and water), the wages of train crews, train supplies and expenses of an accidental nature, such as personal injuries, stock killed, clearing wrecks, and other casualties resulting from the running of trains.

### Car Expenses.

Car expenses include the cost of maintenance, or repairs and renewals of cars, the cost of lubricating them, and other expenses incident to their use. The cost of lighting and heating cars on passenger trains is proportionate to the number of cars in the train, and, therefore, properly a part of the car expenses; but when they are heated by steam from the locomotive it is an additional tax on the motive power, which must add to the consumption of fuel, but will not otherwise increase the motive power expenses.

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### Gross Tonnage Expenses.

The expenses which are necessarily dependent upon the gross ton mileage are the cost of fuel and water, by means of which power is produced, and what it costs to make good the wear and tear of track which results from the power exerted in hauling trains over it. Accounts should be kept of the cost of fuel consumed by each class of trains, and as the evaporation of water is in proportion to the fuel consumed, its cost should be charged in the same proportion as the fuel. If such accounts have not been kept, a distribution of the fuel and water on the basis of the relative gross ton miles of passenger and freight trains will be approximately correct, due allowance being made for the relative speed of passenger and freight trains. The annual wear and tear of track is necessarily to be estimated, for renewals never keep exact pace with it; but whatever is charged for deterioration of rails should be apportioned to passenger and freight trains on the basis of their relative weight and speed.

Should motive power expenses hereafter be determined on a ton mile basis, they may all be treated as gross tonnage expenses, although the wages of engineers and firemen, being based on train mileage, that expense belongs properly in Train Expenses.

Accounts kept as above indicated will give the actual distribution of probably not less than seventy-five per cent. of the expenses, and there can be no reasonable objection to allotting the other twenty-five per cent. or less, which are expenses in common for both passenger and freight, in proportion to the gross ton mileage of each, for the gross ton mile is the nearest approximation to an absolute unit of service in transportation.

The statistical results of this method of analysis, as applied to one hundred and eighty-nine miles of railway in the South for a period of ten years, from 1875 to 1884, may prove interesting, not only as an illustration of the method, but also as indicating approximately the cost of each unit of service:

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## STATISTICS OF PASSENGER TRAINS.

TRAIN MILEAGE, CAR MILEAGE AND GROSS TONNAGE:

| | | |
|---|---|---|
| Miles run by passenger trains, | | 3,094,441 |
| " " passenger coaches, | 5,990,107 | |
| " " baggage cars, | 1,740,289 | |
| " " express cars, | 1,630,857 | |
| " " mail cars, | 1,430,596 | |
| " " sleeping cars, | 2,161,167 | |
| " " special foreign cars, | 17,851 | |
| | | 12,970,867 |
| Gross ton miles of passenger engines, | 159,480,981 | |
| " " cars with passengers, | 212,801,483 | |
| " " " express, | 32,634,932 | |
| " " " mail, | 29,880,699 | |
| | | 434,798,095 |

DEAD AND PAYING LOAD:

| | | Gross ton miles. | | |
|---|---|---|---|---|
| Cars for passengers, | 96.91% | 206,219,403 | | |
| Passengers and baggage, | 3.09% | 6,582,080 | | |
| | | | 77.30% | 212,801,483 |
| Cars for express, | 89.95% | 29,355,426 | | |
| Express freight, | 10.05% | 3,279,506 | | |
| | | | 11.85% | 32,634,932 |
| Cars for mail, | 90.97% | 27,181,324 | | |
| Mail matter, | 9.03% | 2,699,375 | | |
| | | | 10.85% | 29,880,699 |
| Total cars and loads, passenger trains, | | | | 275,317,114 |

AVERAGE WEIGHTS:

| | |
|---|---|
| Passenger train engines, | 51.538 tons |
| Cars with passengers, | 21.330 " |
| Cars with express, | 20.011 " |
| Cars with mail, | 21.887 " |
| Average weight of passenger trains, | 140.509 " |

PASSENGER TRAIN TRAFFIC.

| | |
|---|---|
| Number of passengers, | 1,414,419 |
| Passenger miles, | 78,634,224 |
| Ton miles of express, | 3,279,506 |
| Ton miles of mail, | 2,699,375 |

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AVERAGE LOAD OF PASSENGER TRAINS:

| | |
|---|---|
| Number of passengers, 25.412, | 2.127 tons. |
| Express freight, | 1.060 " |
| Mail matter, | 0.872 " |
| Total load of passenger trains, | 4.059 " |

## STATISTICS OF FREIGHT TRAINS.

TRAIN MILEAGE:

| | | |
|---|---|---|
| Miles run by general tonnage trains, | 4,292,868 | |
| " " coal and stone trains, | 150,577 | |
| " " switching trains, | 47,693 | |
| | | 4,491,138 |

CAR MILEAGE:

| | Loaded. | Empty. | Caboose. | Total. |
|---|---|---|---|---|
| General tonnage, | 57,250,333 | 12,624,801 | 3,974,720 | 73,849,854 |
| Coal and stone, | 372,948 | 348,651 | 1,283 | 722,882 |
| Switching, | 95,671 | 66,212 | ..... | 161,883 |
| Totals, | 57,718,952 | 13,039,664 | 3,976,003 | 74,734,619 |

GROSS TON MILEAGE:

| | Engines. | Cars. | Loads. | Total. |
|---|---|---|---|---|
| General tonnage, | 251,082,053 | 750,412,961 | 377,128,870 | 1,378,623,884 |
| Coal and stone, | 6,554,042 | 4,958,201 | 2,762,031 | 14,274,274 |
| Switching, | 1,982,742 | 1,089,219 | 755,144 | 3,827,105 |
| Totals, | 259,618,837 | 756,460,381 | 380,646,045 | 1,396,725,263 |

DEAD AND PAYING LOAD:

| | | | |
|---|---|---|---|
| Cars for general tonnage, | 66.55% | 750,412,961 | |
| General tonnage, | 33.45% | 377,128,870 | |
| | | | 1,127,541,831 |
| Cars for coal and stone, | 64.22% | 4,958,201 | |
| Coal and stone tonnage, | 35.78% | 2,762,031 | |
| | | | 7,720,232 |
| Cars for switching tonnage, | 59.06% | 1,089,219 | |
| Switching tonnage, | 40.94% | 755,144 | |
| | | | 1,844,363 |
| Total cars and loads freight trains, | | | 1,137,106,426 |

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| AVERAGE WEIGHTS in tons: | Engines. | Cars. | Loads. | Total. |
|---|---|---|---|---|
| General tonnage train, | 58.488 | 174.805 | 87.850 | 321.143 |
| Coal and stone trains, | 43.526 | 32.928 | 18.343 | 94.797 |
| Switching trains, | 41.573 | 22.838 | 15.834 | 80.245 |
| General average, | 57.807 | 168.434 | 84.755 | 310.996 |

| FREIGHT TRAFFIC: | Tons. | Ton miles. | Av'ge haul. |
|---|---|---|---|
| General tonnage through, | 1,130,047 | 188,309,268 | 166.6 |
| General tonnage local, | 1,719,794 | 188,819,602 | 109.8 |
| Coal and stone tonnage, | 337,837 | 2,762,031 | 8.2 |
| Switching tonnage, | 362,842 | 755,144 | 2.1 |
| Total, | 3,550,520 | 380,646,045 | 107.2 |

## OPERATING EXPENSES.

| | Total. | Passenger. | Freight |
|---|---|---|---|
| Administration, | $ 405,163 | $ 96,184 | $308,979 |
| Taxes and insurance, | 68,465 | 16,254 | 52,211 |
| Maintenance of roadway, etc., | 1,067,215 | 253,353 | 813,862 |
| Total fixed expenses, | $1,540,843 | $365,791 | $1,175,052 |
| Ordinary station and terminal expenses, | $749,821 | $179,646 | $570,175 |
| Special terminal expenses, | 201,618 | 124,602 | 77,016 |
| Total station and terminal expenses, | $951,439 | $304,248 | $647,191 |
| Motive power, | $908,633 | $259,177 | $649,456 |
| Train service and supplies, | 451,163 | 124,835 | 326,328 |
| Casualties, | 162,322 | 51,649 | 110,673 |
| Total train expenses, | $1,522,118 | $435,661 | $1,086,457 |
| Maintenance of cars, | $697,203 | $226,325 | $470,878 |
| Car service and supplies, | 157,860 | 86,475 | 71,385 |
| Total car expenses, | $855,063 | $312,800 | $542,263 |
| Fuel and water, | $782,379 | $214,979 | $567,400 |
| Repairs of track, | 299,729 | 99,845 | 199,884 |
| Renewals of track, | 464,753 | 154,817 | 309,936 |
| Betterments of track, | 254,178 | 84,671 | 169,507 |
| Total gross tonnage expenses, | $1,801,039 | $554,312 | $1,246,727 |

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### RECAPITULATION OF EXPENSES.

| | Total. | Passenger. | Freight. |
|---|---|---|---|
| Fixed expenses, | $1,540,843 | $365,791 | $1,175,052 |
| Station and terminal expenses, | 951,439 | 304,248 | 647,191 |
| Train expenses, | 1,522,118 | 435,661 | 1,086,457 |
| Car expenses, | 855,063 | 312,800 | 542,263 |
| Gross tonnage expenses, | 1,801,039 | 554,312 | 1,246,727 |
| Total operating expenses, | $6,670,502 | $1,972,812 | $4,697,690 |

## UNITS OF COST OF PASSENGER AND FREIGHT SERVICE.

### AVERAGE FOR TEN YEARS.

| | Per Mile of Road, Per Annum. | | Per Gross Ton Mile. | |
|---|---|---|---|---|
| | Passenger. | Freight. | Passenger. | Freight. |
| Fixed Expenses. | | | Cents. | Cents. |
| Administration, | $ 50.89 | $163.48 | 0.022122 | 0.022122 |
| Taxes and insurance, | 8.60 | 27.62 | 0.003738 | 0.003738 |
| Maintenance of road, | 134.05 | 430.62 | 0.058269 | 0.058269 |
| Total, | $193.54 | $621.72 | 0.084129 | 0.084129 |

| | Per passenger. | Per ton. | | |
|---|---|---|---|---|
| Terminal and Station Expenses: | Cents. | Cents. | | |
| Ordinary, | 12.701 | 16.059 | 0.041317 | 0.040822 |
| Special, | 8.809 | 2.169 | 0.028657 | 0.005514 |
| Total, | 21.510 | 18.228 | 0.069974 | 0.046336 |

| | Per Train Mile. | | | |
|---|---|---|---|---|
| | Passenger. | Freight. | | |
| Train Expenses: | Cents. | Cents. | | |
| Motive power, | 8.376 | 14.461 | 0.059609 | 0.046497 |
| Train service and supplies, | 4.034 | 7.266 | 0.028711 | 0.023365 |
| Casualties, | 1.669 | 2.464 | 0.011878 | 0.007924 |
| Total, | 14.079 | 24.191 | 0.100198 | 0.077786 |

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| Car Expenses: | Per Car Mile. Passenger. Cents. | Freight. Cents. | | |
|---|---|---|---|---|
| Maintenance of cars, | 1.74488 | 0.63007 | 0.052053 | 0.033713 |
| Car service and supplies, | 0.66669 | 0.09552 | 0.019888 | 0.005110 |
| Total, | 2.41157 | 0.72559 | 0.071941 | 0.038823 |

| Gross Tonnage Expenses: | Per Gross Ton Mile. Passenger. Cents. | Freight. Cents. |
|---|---|---|
| Fuel and water, | 0.049444 | 0.040624 |
| Repairs of track, | 0.022963 | 0.014311 |
| Renewal of rails,* | 0.035607 | 0.022190 |
| Total, | 0.108014 | 0.077125 |

RECAPITULATION.

| | | |
|---|---|---|
| Fixed expenses, | 0.084129 | 0.084129 |
| Terminal and station expenses, | 0.069974 | 0.046336 |
| Train expenses, | 0.100198 | 0.077786 |
| Car expenses, | 0.071941 | 0.038823 |
| Gross tonnage expenses, | 0.108014 | 0.077125 |
| Total, | 0.434256 | 0.324199 |

* Betterments to track, which cost $254,178, not included in cost of Renewals of Rails.

---

The above are the actual averages for ten years on the road in question, but during that period the gross tonnage expenses were to some extent abnormal for two reasons:

*First.* By reason of the gradual substitution of coal for wood as fuel for locomotives, which was begun as soon as the cost of coal per ton approximated to the cost of an equivalent amount of wood. This made the actual expenditure for fuel for ten years somewhat more than it would have been if coal had been available during the whole period, at a reasonable price.

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*Second.* The iron rails in the track at the beginning of the ten years were much worn, and the substitution of steel rails during that period not only constituted in part a betterment which is so charged above, but after giving this credit the cost of maintenance of track was more than it would have been if steel rails, with their greater endurance, had been used exclusively. The above ascertained cost of "renewal of rails," being for mixed iron and steel rails, is therefore in excess of what it should be for 60-lb. steel rails.

Similar accounts were kept of the expenses of other roads during the same and a subsequent period, the results of which, compared with the foregoing, lead to the conclusion that under generally similar conditions, and especially during the same period under similar conditions, there is little variation in the cost of the same class of service on different roads. General averages of cost were ascertained from a number of different southern roads for from three to ten years, but the averages given above differ little therefrom, and are believed to be more reliable, on account of the greater care with which the accounts were kept on this particular road.

## Fixed Charges.

Interest and rentals, while not classed as expenses, are nevertheless an obligation to be provided for out of earnings.

The profits of the farmer depend upon the cost of producing his crops and the prices at which he can market them; the profits of the manufacturer, upon what he pays for the raw material, the cost of manufacturing it, and the prices he can get for his finished product. In either case there is money invested in the business, the interest on which is taken into account in determining the cost of production.

Transportation is the product of a railway, and interest on the capital invested in the business is not only a part of the cost of transportation, but is an obtrusive element of cost, for the reason that railways are largely, if not exclusively, built with borrowed capital, evidenced by securities, the holders of which want their interest with great regularity, and failing to get it, are prompt to inaugurate foreclosure proceedings.

In order to keep down the interest charges on a railway, cheapness in construction is often resorted to, but not so often for this purpose as to swell the

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profits of a construction company. After a railway is built, if its traffic develops satisfactorily, and net earnings are large in proportion to the capital originally invested, the output of bonds or other evidence of indebtedness may be increased, if only for the purpose of properly capitalizing the earning capacity of the property, and interest obligations may or may not remain fixed; but if they should be swelled out of proportion to the earning capacity of the road, reorganization or foreclosure intervenes to readjust them.

Whatever the fixed charges on a railway may be, the manager is expected to make the net earnings suffice to meet them, and to him they are an element in the cost of transportation, of more or less per mile of road operated, to meet which he must, if necessary, forego much needed improvements, and keep down operating expenses to the minimum.

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## CHAPTER V.

### Cost of Different Classes of Service Performed by Revenue Trains.

If we have successfully resolved the operations of the railway in question into the elements of service performed, and ascertained the cost of each unit of service, we can determine the relative cost, not only of the passenger and freight traffic, but of each of the several classes of tonnage, as follows:

UNITS OF COST OF FREIGHT SERVICE.

| | | Cents. |
|---|---|---|
| Terminal expenses per ton of freight, | | 18.228 |
| Train expenses per train mile, | | 24.191 |
| Car expenses per car mile, | | 0.72559 |
| Fuel and water per gross ton mile, | 0.040624 | |
| Repairs of track per gross ton mile, | 0.014311 | |
| Renewal of rails,* per gross ton mile, | 0.022190 | |
| Fixed expenses per gross ton mile, | 0.084129 | |
| | | 0.161254 |

* Exclusive of betterments to track.

UNITS OF FREIGHT SERVICE.

| | Tons. | Train miles. | Car miles. | Gross ton miles. |
|---|---|---|---|---|
| General tonnage, | 2,849,841 | 4,292,868 | 73,849,854 | 1,378,623,884 |
| Coal and stone, | 337,837 | 150,577 | 722,882 | 14,274,274 |
| Switching, | 362,842 | 47,693 | 161,883 | 3,827,105 |
| | 3,550,520 | 4,491,138 | 74,734,619 | 1,396,725,263 |

Applying the above units of cost to the service performed for each class of tonnage, we have as the cost of each—

COST OF FREIGHT SERVICE DISTRIBUTED.

| | General tonnage. | Stone and coal. | Switching. | Total. |
|---|---|---|---|---|
| Terminal expenses, | $ 519,471 | $61,581 | $66,139 | $ 647,191 |
| Train expenses, | 1,038,492 | 36,427 | 11,538 | 1,086,457 |
| Car expenses, | 535,843 | 5,245 | 1,175 | 542,263 |
| Gross tonnage and fixed expenses, | 2,223,083 | 23,018 | 6,171 | 2,252,272 |
| | $4,316,889 | $126,271 | $85,023 | $4,528,183 |

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| | General tonnage. Cents. | Stone & coal. Cents. | Switching. Cents. |
|---|---|---|---|
| Per ton, | 151.48 | 37.38 | 23.43 |
| Per train mile, | 100.56 | 83.86 | 178.27 |
| Per car mile, | 5.8455 | 17.4677 | 52.5212 |
| Per gross ton mile, | 0.31311 | 0.884605 | 2.221601 |
| Per ton mile freight, | 1.14467 | 4.57167 | 11.25917 |
| Average haul, in miles, | 132.33 | 8.18 | 2.08 |

No better illustration could be made of the effect of improved conditions on Southern Railways than by a comparison of the above cost of transporting freight with recent results.

A new era in railroad transportation in the South began very nearly at the expiration of the ten years during which the above statistics were obtained, for prior to that time steel rails were costly, and only roads with great density of traffic could afford to use the heavier sections, which have made it practicable to double the weight of locomotives, and greatly increase the weight and capacity of freight cars. Since that time the railways have not only kept pace with the industrial enterprises in the South, but, by improving the transportation service in advance of actual requirements, made practicable the industrial development of which they are now reaping the benefits.

We have no statistics for any subsequent period with which to make a comparison in detail, but with such as we have, it will not be difficult to show that, with steel rails, ballasted track, heavy locomotives, cars of larger capacity, and more, perhaps than all else, a large increase in the density of freight traffic, great reduction in the cost of conducting transportation would necessarily follow.

## SUBDIVISION OF PASSENGER TRAIN EXPENSES.

The train, car and gross tonnage expenses of passenger trains include the cost of hauling Express and Mail, as well as passengers, and they may be subdivided on the following basis.

*First.* Train expenses, being common to the three classes of service on passenger trains, may be distributed in proportion to the relative gross ton mileage of the cars and their loads.

*Second.* Car Expenses may be distributed in proportion to the relative car mileage, taking into consideration the fact that three cents per mile was paid for the use of Pullman Sleepers, and included in the cost of "Maintenance of Cars."

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*Third.* Gross Tonnage Expenses are necessarily in proportion to the gross ton mileage of the three classes of service, and must be distributed on that basis.

The relative proportion of car mileage in the three classes of service, exclusive of Sleepers, was as follows:

| | Car mileage. | | Per cent. |
|---|---|---|---|
| For passengers, | 7,748,247 | .... | 71.67 |
| For express, | 1,630,857 | .... | 15.09 |
| For mail, | 1,430,596 | .... | 13.24 |
| | 10,809,700 | .... | 100.00 |

The relative proportion of gross ton mileage of the three classes of service was as follows:

| | Ton miles. | | Per cent. |
|---|---|---|---|
| For passenger, | 212,801,483 | .... | 77.29 |
| For express, | 32,634,932 | .... | 11.86 |
| For mail, | 29,880,699 | .... | 10.85 |
| Total, | 275,317,114 | .... | 100.00 |

The "Fixed Expenses" are also chargeable on the basis of the gross ton mileage, but the Station and Terminal expenses pertain to the passenger traffic alone, and, merging such expenses as are distributable on the same basis, we have—

| | | | |
|---|---|---|---|
| Fixed expenses, | | $365,791 | |
| Train expenses, | | 435,661 | |
| Gross tonnage expenses, | | 554,312 | |
| | | | $1,355,764 |
| Passenger, | 77.29% | .... | $1,047,870 |
| Express, | 11.86% | .... | 160,794 |
| Mail, | 10.85% | .... | 147,100 |

From the car expenses we must first deduct the three cents per mile for sleeping cars, and distribute the remainder as follows:

| | | |
|---|---|---|
| Total car expenses, | $312,800 | |
| Less 2,161,167 × 3, | 64,835 | |
| | | $247,965 |

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| | | | |
|---|---|---|---|
| Passenger, | 71.67 | .... | 177.717 |
| Express, | 15.09 | .... | 37.418 |
| Mail, | 13.24 | .... | 32.830 |

Consolidating the foregoing, we have—

| | | | |
|---|---|---|---|
| PASSENGER: | | | |
| Fixed train and gross tonnage expenses, | | $1,047,870 | |
| Station and terminal expenses, | | 304,248 | |
| Car expenses, passenger and baggage, | 177,717 | | |
| Sleepers, | 64,835 | | |
| | | 242,552 | |
| | | | $1,594,670 |
| EXPRESS: | | | |
| Fixed train and gross tonnage expenses, | | $160,794 | |
| Car expenses, | | 37,418 | |
| | | | 198,212 |
| MAIL: | | | |
| Fixed train and gross tonnage expenses, | | $147,100 | |
| Car expenses, | | 32,830 | |
| | | | 179,930 |
| Total expenses passenger trains, | | | $1,972,812 |

| | | |
|---|---|---|
| Passengers, cost per train mile, | 51.533 | cents |
| Express, cost per train mile, | 6.405 | " |
| Mail, cost per train mile, | 5.815 | " |
| Total per passenger train mile, | 63.753 | " |

| | | |
|---|---|---|
| Passenger cost per car mile, | 16.092 | cents |
| Express cost per car mile, | 12.154 | " |
| Mail cost per car mile, | 12.577 | " |
| Average cost per car mile, | 15.210 | " |

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## CHAPTER VI.

### Consumption of Fuel by Locomotives.

THE consumption of coal by locomotives on the same road for a period of one year was as follows:

| | Passenger. | Freight. | Switching. | Service. |
|---|---|---|---|---|
| Tons of coal, | 7,303 | 25,134 | 2,508 | 1,287 |
| Train miles, | 311,294 | 664,718 | 171,165 | 46,685 |
| Car miles, | 1,393,694 | 12,510,571 | 764,450 | 374,202 |
| Gross weight of train, | 162.13 | 361.76 | 112.69 | 167.31 |
| Pounds coal per train mile, | 46.920 | 75.623 | 29.305 | 55.135 |
| Pounds coal per car mile, | 10.481 | 4.018 | 6.562 | 6.878 |
| Pounds coal per gross ton mile, | 0.28942 | 0.20904 | 0.26005 | 0.32954 |

The average speed of passenger and freight trains was, as nearly as could be ascertained at the time, as follows:

Passenger trains, 26 miles per hour.
Freight trains, 16 miles per hour.

In order to ascertain the useful effect obtained from the above consumption of coal, we must take into consideration the characteristics of the road as follows:

### CHARACTERISTICS OF ROAD.

| | | |
|---|---|---|
| Length of level track in miles, | | 38.576 |
| Length of grades ascending west, | | 88.386 |
| Length of grades descending west, | | 62.038 |
| Total length of road, | | 189.000 |
| Length of straight line, | 125.0 | |
| Length of curves, | 64.0 | |
| | | 189.0 |
| Total curvature in degrees, | | 7,905.00 |
| Average curvature in degrees, | | 2.34 |
| Degrees per mile of curved line, | | 123.52 |
| Average degrees of curvature per mile of road, | | 41.82 |

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| Ascending Grades Going West: | Miles. | Ascent. | Per mile. |
|---|---|---|---|
| 20 feet per mile and less, | 21.161 | 184.4 | 8.71 |
| 20.82 feet to 26.93 feet per mile, | 4.236 | 102.1 | 24.10 |
| 27.26 feet per mile and over, | 62.989 | 3081.5 | 48.92 |
| Total, | 88.386 | 3368.0 | 38.10 |

Average ascent per mile for 189 miles going west, 17.82 feet.

| Ascending Grades Going East: | | | |
|---|---|---|---|
| 20 feet per mile and less, | 12.105 | 152.0 | 12.55 |
| 20.82 feet to 26.93 feet per mile, | 2.897 | 75.5 | 26.06 |
| 27.26 feet per mile and over, | 47.036 | 2333.5 | 49.61 |
| Total, | 62.038 | 2561.0 | 41.28 |

Average ascent per mile for 189 miles going east, 13.55 feet.

## Tractive Power of Locomotives.

The tractive *power* of a locomotive is limited by the weight on its driving wheels, and the ratio of their adhesion to the rails, while the tractive *force* of a locomotive depends upon the diameter of the cylinders, length of stroke, diameter of driving wheels, and steam pressure on the boiler.

If a locomotive engine were raised above the rails instead of its wheels resting on them, the power required to revolve its driving wheels would be such as is necessary to overcome its internal resistance while working as a stationary engine without any load, and this resistance must be overcome before any power is available at the periphery of the driving wheels. There is also a loss of effective steam pressure between the boiler and the cylinders; and to make proper allowance for both internal resistance and loss of steam pressure it is usual, in calculating tractive force, to assume that only 85 per cent. of the pressure of steam in the boiler will be available in the cylinders. This is generally provided for by the builders of locomotives, so that the tractive force will overcome the greatest resistance which the weight on the drivers and their adhesion to the rails under favorable conditions will oppose to it. This done, the weight on the driving wheels, and the ratio of their adhesion to the rails, practically determines the tractive power of the locomotive, so long as the proper pressure of steam is maintained. The steam pressure

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should, so far as practicable, be regulated so as to furnish no more tractive force than can be made available at the time, as tractive power; for any excess means a waste of fuel.

The tractive power exerted by a locomotive is partly expended in moving itself, for the effective work done includes the movement of the locomotive and tender as well as the train hauled, and if we know the gross ton miles moved, the average resistance per gross ton mile, and the consumption of coal, we can determine the tractive power exerted by the locomotive per unit of coal consumed.

### Train Resistances.

The resistance due to friction is directly in proportion to the distance, and has been ascertained to be 6 pounds per ton, or 31,680 foot pounds per gross ton mile.

The resistance due to speed increases as the square of the speed divided by 172, and is 7,858 foot pounds per gross ton mile at 16 miles per hour, and 20,751 foot pounds per gross ton mile at 26 miles per hour.

The resistance per gross ton mile due to curvature is in proportion to the number of degrees of curvature per mile, at one-half a pound for each degree of deflection per 100 feet, and in this case averages 2,091 foot pounds per gross ton mile for the whole length of the road, and per mile of curved line 6,176 foot pounds.

### Relative Consumption of Fuel.

The consumption of fuel should be less on descending grades than on a level; but there can be no absolute cessation of its consumption, for the fires must be maintained, and when the boiler pressure has been reduced in overcoming ascents it must be restored before the next ascent is reached. Thus it becomes necessary to keep up the fires on descending grades, unless the descent is continuous for so long a distance as to admit of "banking" them for a part of it, which was not the case on the road in question.

With passenger trains about 29 per cent., and with freight trains about 31 per cent. of the round trips required no steam power to move the train, but coal was being consumed to accumulate steam while none was being used, and the question is how much fuel was so consumed. This would depend largely upon

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what proportion of the steam necessary to provide power requisite to overcome ascents could be generated during the time ascents were being overcome, and what proportion must be accumulated during the intervals between ascents, to overcome which called for more steam than the boiler would furnish during the time the heavy work was being done in overcoming ascents.

In the case under consideration the locomotives used were, it would seem, worked nearly to the full steam-making power of their boilers for their schedule time, and the consumption of fuel was very nearly at the maximum for the area of their grate surface all the time they were running. In other words, it required all the steam they could generate moving down grade to help them over the next ascent. This conclusion is sustained by the fact that the average consumption of coal per hour was nearly the same by passenger trains of 162 tons at 26 miles per hour, and freight trains of 362 tons at 16 miles per hour.

There seems to be little doubt, if any, that the consumption of coal is less in proportion to the work done, when the locomotive has boiler capacity and steaming qualities that enable it to overcome the heaviest resistance without materially reducing the steam pressure in the boiler; or, in other words, when it is not forced beyond the legitimate capacity of the boiler.

## Resistance per Gross Ton Mile.

The resistances opposed to the movement of trains, at 26 and 16 miles per hour, over the 189 miles in both directions, and the power used to overcome them, were as follows, per gross ton mile:

| Going West at 26 miles per hour: | Foot pounds. |
|---|---|
| 189 miles (friction and speed), at 52,431 foot pounds, | 9,909,459 |
| 64 miles (curvature), at 6,176 foot pounds, | 395,264 |
| Sum of ascents, 3,368 feet, at 2,000 pounds, | 6,736,000 |
| Total resistance per gross ton mile, | 17,040,723 |
| Less gravity utilized on 15.002 miles, 227.5 feet, at 2,000 pounds, | 455,000 |
| Less gravity utilized on 47.036 miles, at 52,431 foot pounds, | 2,466,145 |
| | 2,921,145 |
| Power supplied by locomotive, | 14,119,578 |
| Gravity power neutralized by brakes, | 2,200,855 |

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GOING EAST at 26 miles per hour:

| | Foot pounds. |
|---|---|
| 189 miles (friction and speed), at 52,431 foot pounds, | 9,909,459 |
| 64 miles (curvature), at 6,176 foot pounds, | 395,264 |
| Sum of ascents, 2,561 feet, at 2,000 pounds, | 5,122,000 |
| Total resistance per gross ton mile, | 15,426,723 |
| Less gravity utilized on 25.397 miles, 286.5 feet, at 2,000 pounds, ... 573,000 | |
| Less gravity utilized on 62.989 miles, at 52,431 foot pounds, .....3,302,576 | |
| | 3,875,576 |
| Power supplied by locomotive, | 11,551,147 |
| Gravity power neutralized by brakes, | 2,860,424 |

GOING WEST at 16 miles per hour:

| | |
|---|---|
| 189 miles (friction and speed), at 39,538 foot pounds, | 7,472,682 |
| 64 miles (curvature), at 6,176 foot pounds, | 395,264 |
| Sum of ascents, 3,368 feet, at 2,000 pounds, | 6,736,000 |
| Total resistance per gross ton mile, | 14,603,946 |
| Less gravity utilized on 12.105 miles, 152.0 feet, at 2,000 pounds, ... 304,000 | |
| Less gravity utilized on 49.933 miles, at 39,538 foot pounds, .....1,974,251 | |
| | 2,278,251 |
| Power supplied by locomotive, | 12,325,695 |
| Gravity power neutralized by brakes, | 2,843,749 |

GOING EAST at 16 miles per hour:

| | |
|---|---|
| 189 miles (friction and speed), at 39,538 foot pounds, | 7,472,682 |
| 64 miles (curvature), at 6,176 foot pounds, | 395,264 |
| Sum of ascents, 2,561 feet, at 2,000 pounds, | 5,122,000 |
| Total resistance per gross ton mile, | 12,989,946 |
| Less gravity utilized on 21.161 miles, 184.4 feet, at 2,000 pounds, ... 368,800 | |
| Less gravity utilized on 67.225 miles, at 39,538 foot pounds, .....2,657,942 | |
| | 3,026,742 |
| Power supplied by locomotive, | 9,963,204 |
| Gravity neutralized by brakes, | 3,709,258 |

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## RECAPITULATION.

**PASSENGER TRAINS:**

| | Foot pounds. | |
|---|---|---|
| Power supplied by locomotives going west, | 14,119,578 | |
| Power supplied by locomotives going east, | 11,551,147 | |
| | | 25,670,725 |
| Gravity utilized going west, | 2,921,145 | |
| Gravity utilized going east, | 3,875,576 | |
| | | 6,796,721 |
| Total resistance both ways per gross ton mile, | | 32,467,446 |
| Excess of available gravity going west, | 2,200,855 | |
| Excess of available gravity going east, | 2,860,424 | |
| | | 5,061,279 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ratio of gravity utilized to steam power | | | | going west, | 20.69 | per cent. |
| " | " | " | " | going east, | 33.55 | " " |
| " | " | " | " | both ways, | 26.48 | " " |
| " | " | wasted | " | going west, | 15.58 | " " |
| " | " | " | " | going east, | 24.76 | " " |
| " | " | " | " | both ways, | 19.72 | " " |

**FREIGHT TRAINS:**

| | Foot pounds. | |
|---|---|---|
| Power supplied by locomotives going west, | 12,325,695 | |
| Power supplied by locomotives going east, | 9,963,204 | |
| | | 22,288,899 |
| Gravity utilized going west, | 2,278,251 | |
| Gravity utilized going east, | 3,026,742 | |
| | | 5,304,993 |
| Total resistance both ways per gross ton mile, | | 27,593,892 |
| Excess of available gravity going west, | 2,843,749 | |
| Excess of available gravity going east, | 3,709,258 | |
| | | 6,553,007 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Ratio of gravity utilized to steam power | | | | going west, | 18.48 | per cent. |
| " | " | " | " | going east, | 30.38 | " " |
| " | " | " | " | both ways, | 23.80 | " " |
| " | " | wasted | " | going west, | 23.07 | " " |
| " | " | " | " | going east, | 37.23 | " " |
| " | " | " | " | both ways, | 29.40 | " " |

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The ratio of additions to locomotive power from the utilization of gravity to propel both passenger and freight trains on descending grades, and of the excess of gravity power wasted, were as follows:

| | Utilized. | Wasted. |
|---|---|---|
| Going west, | 19.66 per cent. | 19.08 per cent. |
| Going east, | 32.08 " " | 30.53 " " |
| Both ways, | 25.23 " " | 24.22 " " |

This shows that, as the result of every one hundred foot pounds of energy exerted by locomotives, 49.45 foot pounds of kinetic force were stored, and the *maximum of useful effect* would have been obtained if all of it could have been made available to move trains on descending grades. Owing, however, to the characteristics of the road, only 25.23 foot pounds of this kinetic force was utilized as an addition to each 100 foot pounds of energy furnished by the locomotive, and the ratio of useful effect was as 149.45 to 125.23 or 83.79 per cent., the maximum of useful effect not being attainable with grades of over 25 to 30 feet per mile.

### Resistance per Train Mile.

Passenger trains averaged 162.13 tons, and were about the same each way; but freight trains were heavier going west, on account of a preponderance of traffic in that direction. Their average weight was 361.76 tons, of which 269.23 was dead load, and their relative weight in each direction was as follows:

| | Going West. | Going East. |
|---|---|---|
| Dead load, | 269.23 tons. | 269.23 tons. |
| Paying load, | 121.40 " | 63.66 " |
| Total, | 390.63 " | 332.89 " |

If we multiply the weight of each class of trains in tons by the above ascertained resistance per gross ton mile in each direction, we will have the work done in foot pounds per train mile by each as follows:

Passenger trains west, ..... $162.13 \times 14{,}119{,}578 = 2{,}289{,}207{,}181$
Passenger trains east, ..... $162.13 \times 11{,}551{,}147 = 1{,}872{,}787{,}463$

Total foot pounds, ..... 4,161,994,644

Average per train mile for a round trip of 378 miles, 11,010,568 foot pounds.

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Freight trains west, .....390.63 × 12,325,695 = 4,814,786,238
Freight trains east, .....332.89 × 9,963,204 = 3,316,650,980

Total foot pounds, ..... 8,131,437,218
Average per train mile for a round trip of 378 miles, 21,511,739 foot pounds.

## Available Power from One Pound of Coal.

The average power required per train mile, and the consumption of coal per train mile having been ascertained as above for both passenger and freight trains, the power from one pound of coal made available in moving trains was as follows:

On passenger trains, .....11,010,568 ÷ 46.920 = 234,667 foot pounds.
On freight trains, .....21,511,739 ÷ 75.623 = 284,460 foot pounds.

## Coal per Horse Power Hour.

The coal consumed per hour, the horse power hours of energy produced and pounds of coal per horse power hour were as follows:

| | Coal per hour. | H. P. hours of energy. | Coal per H. P. hour. |
|---|---|---|---|
| On passenger locomotives, ..... | 1,220 pounds. | 144.59 .... | 8.438 pounds. |
| On freight locomotives, ..... | 1,210 " | 173.83 .... | 6.961 " |

It is usual I believe to compare the consumption of coal by locomotives on the basis of the total train resistances, assuming that they are all overcome by steam power without any assistance from gravity, and on this basis we would have—

| | Passenger. | Freight. |
|---|---|---|
| Resistance per gross ton mile, in foot pounds, ..... | 32,467,446 | 27,593,892 |
| Average per train mile, in foot pounds, ..... | 13,925,786 | 26,531,647 |
| Foot pounds per pound of coal, ..... | 296,780 | 350,841 |
| Horse power hours of energy, ..... | 182.86 | 214.40 |
| Pounds of coal per horse power hour, ..... | 6.67 | 5.64 |

The total resistance per gross ton mile overcome by passenger trains was 17.66 per cent. more than on freight trains, but the coal consumed per gross ton mile was 38.45 more at the higher speed. This was apparently due to a waste of steam resulting from the fires being forced; and if we take into account the gravity

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utilized, the power supplied by the passenger locomotives was only 15.17 per cent. more per gross ton mile, with 38.45 per cent. more coal consumed per gross ton mile.

### Recent Trial Runs.

The following are the results of some recent trial runs with heavy modern locomotives, showing the consumption of coal in proportion to the total train resistance (exclusive of curvature), no account being taken of gravity utilized on descending grades. It is evident from the profiles that gravity was utilized to a considerable extent, but details, necessary to ascertain the extent to which gravity assisted in the movement of the trains are lacking.

On a run of 172 miles, with an average ascent of 5.32 feet per mile, a passenger train of 550 tons, at a speed of 40.5 miles per hour, consumed 109.4 pounds of coal per train mile, or 4,430.7 pounds per hour. The average resistance was 92,670 foot pounds per gross ton mile, and 50,968,500 foot pounds per train mile. From this it would appear that one pound of coal produced power enough to overcome 465,891 foot pounds of resistance, and that 4,430.7 pounds of coal produced the equivalent of 1,042.54 horse power hours of work, which is at the rate of 4.25 pounds of coal per horse power hour. Coal consumed, per gross ton mile, was 0.1989 pounds.

A freight train of 2,000 tons, running over the same track at a speed of 20 miles per hour, consumed 237 pounds of coal per train mile, or 4,740 pounds per hour. The average resistance was 54,599 foot pounds per gross ton mile, and 109,198,000 foot pounds per train mile, from which it would appear that one pound of coal produced power enough to overcome 460,751 foot pounds of resistance, and that 4,740 pounds of coal produced the equivalent of 1,103.02 horse power hours of work, which is at the rate of 4.297 pounds of coal per horse power hour. Coal consumed, per gross ton mile, was 0.1185 pounds.

On another part of the same railway system, with an average ascent of 13.06 feet per mile, a passenger train of 325 tons, at a speed of 31 miles per hour, consumed 60 pounds of coal per train mile, or 1,860 pounds per hour. The average resistance was 87,300 foot pounds per gross ton mile, and 28,372,500 foot pounds per train mile, from which it would appear that one pound of coal produced power enough to overcome 472,875 foot pounds of resistance, and that 1,860 pounds of

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coal produced the equivalent of 444.22 horse power hours of work, which is at the rate of 4.187 pounds of coal per horse power hour. Coal consumed per gross ton mile was 0.1846 pounds.

A freight train of 2,000 tons, over the last mentioned road, at a speed of 20 miles per hour, consumed 304.6 pounds of coal per train mile, or 6,092 pounds per hour. The average resistance was 70,079 foot pounds per gross ton mile, and 140,158,000 foot pounds per train mile, from which it would appear that one pound of coal produced power enough to overcome 460,138 foot pounds of resistance, and that 6,092 pounds of coal produced the equivalent of 1415.74 horse power hours of work, which is at the rate of 4.303 pounds of coal per horse power hour. Coal consumed per gross ton mile was 0.1523 pounds.

Recapitulating the foregoing results we have—

| Class of trains. | Speed per hour. Miles. | Av'ge Ascent per mile. Feet. | Coal consumed. Per horse-power hour. Pounds. | Coal consumed. Per gross ton mile. Pounds. |
|---|---|---|---|---|
| Passenger, | 40.5 | 5.32 | 4.250 | 0.1989 |
| Freight, | 20.0 | 5.32 | 4.297 | 0.1185 |
| Passenger, | 31.0 | 13.06 | 4.187 | 0.1846 |
| Freight, | 20.0 | 13.06 | 4.303 | 0.1523 |

Comparing the consumption of coal per gross ton mile on the two freight runs at the same speed, but different rates of ascent per mile, we have 0.0338 pounds of additional coal consumed to overcome 7.74 feet more ascent per mile with one ton of weight, which is at the rate of 458,000 foot pounds per pound of coal, about the same that we have ascertained for the two freight trains above, and the greater ascent overcome accounts for the increased consumption of coal per gross ton mile.

If we assume that the same amount of coal per ton was consumed by the passenger trains to overcome the additional ascent of 7.74 feet per mile, the relative consumption at the two speeds of 40.5 and 31 miles per hour, with the same rate of ascent per mile, would have been 0.1989 and 0.1508 pounds per gross ton mile, an increase of 31.89 per cent. in coal per gross ton mile to attain 30.65 per cent. more speed.

The relative resistances per gross ton mile, at 31 and 40.5 miles per hour, for the ascent of 5.32 feet per mile, are as follows:

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| | At 31 miles. | | At 40.5 miles. | |
|---|---|---|---|---|
| Friction, | 31,680 | foot pounds. | 31,680 | foot pounds. |
| Speed, | 29,500 | " " | 50,350 | " " |
| Gravity, | 10,640 | " " | 10,640 | " " |
| Total, | 71,820 | " " | 92,670 | " " |
| Ratio, | 100.00 | | 129.03 | |

We are unable to ascertain to what extent gravity assisted in the movement of trains, or to what extent resistance may have been increased by more curvature, but more of the force of gravity was undoubtedly available at the higher rate of speed, for some descending grades exceeded 30 feet per mile, and we may safely assume that the additional resistance, at the higher speed, could not have been more than 29 per cent., to overcome which it required 31.83 per cent. more coal. This indicates some waste of steam power at higher speeds.

### Available Power Derived from One Pound of Coal.

We have ascertained that the average power derived from one pound of coal in operating passenger trains on a road of undulating grades was 234,652 foot pounds, and that an average of 284,460 foot pounds of power have been developed from one pound of coal in the regular operation of freight trains. In estimating the cost of power required to operate a projected line of railway, it would not be safe to assume, even with improved locomotives, that an average of more than 400,000 foot pounds of available power can be obtained from one pound of coal in the regular operation of the road, and probably not over 350,000.

### Relative Cost of Fuel for Locomotives at Different Periods.

As has already been stated, a change was made in the character of fuel for locomotives during the ten years of operation of the road in question, and it may be interesting to note the relative cost of fuel, per gross ton mile, for each of the ten years. During the first seven years wood was used almost exclusively, the first coal burning engine having been put on the road during the third year, and for several years following the price of wood was so low, and the price of coal so high, that there was no inducement to substitute coal for wood, until the eighth year, when the advanced price of wood, and a reduction in the price of coal, made it

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advisable to change all locomotives to coal burners. This was accomplished in two years, so that during the tenth year no wood was used on either passenger or freight trains, except for kindling fires.

STATEMENT SHOWING COST OF FUEL PER GROSS TON MILE.

| Years. | Passenger Trains. | | | Freight Trains. | | |
|---|---|---|---|---|---|---|
| | Gross tonnage. | Cost of fuel. | Per gross ton mile. | Gross tonnage. | Cost of fuel. | Per gross ton mile. |
| First, ..... | 37,991,916 | $20,655.21 | 0.05437 | 57,759,476 | $32,305.59 | 0.05593 |
| Second, ..... | 29,831,986 | 16,634.98 | 0.05576 | 62,647,611 | 37,439.43 | 0.05976 |
| Third, ..... | 30,493,360 | 12,469.47 | 0.04089 | 74,285,426 | 35,714.88 | 0.04808 |
| Fourth, ..... | 36,209,338 | 13,098.62 | 0.03618 | 81,575,865 | 33,552.24 | 0.04113 |
| Fifth, ..... | 40,578,216 | 12,979.95 | 0.03199 | 125,223,028 | 33,966.19 | 0.02712 |
| Sixth, ..... | 47,553,995 | 14,109.27 | 0.02966 | 151,144,796 | 37,939.77 | 0.02510 |
| Seventh, ..... | 59,398,954 | 22,742.21 | 0.03829 | 164,823,075 | 46,361.39 | 0.02812 |
| Eighth, ..... | 52,244,304 | 24,310.34 | 0.04653 | 209,295,238 | 69,070.29 | 0.03300 |
| Ninth, ..... | 50,026,420 | 28,260.61 | 0.05649 | 229,500,991 | 91,473.30 | 0.03986 |
| Tenth, ..... | 50,469,606 | 22,776.69 | 0.04513 | 240,469,757 | 88,383.92 | 0.03676 |
| Total, .. | 434,798,095 | $188,037.35 | 0.04325 | 1,396,725,263 | $506,207.00 | 0.03624 |

## Cost of Water for Locomotives.

The water supply for locomotives was obtained almost entirely by pumping from streams and wells, and its cost per gross ton mile averaged 12.6 per cent. of the cost of fuel for revenue trains as follows:

| | Passenger Trains. | | Freight Trains. | | Total Cost. |
|---|---|---|---|---|---|
| | Cost. | Per gross ton mile. | Cost. | Per gross ton mile. | |
| Fuel, ..... | $188,037 | 0.04325 | $506,207 | 0.03624 | $694,244 |
| Water, ..... | 26,942 | 0.00619 | 61,193 | 0.00438 | 88,135 |
| Total, ..... | $214,979 | 0.04944 | $567,400 | 0.04062 | $782,379 |

Ratio of water to fuel—passenger, ..... 14.33 per cent.
" " " freight, ..... 12.09 " "
" " " revenue trains, ..... 12.60 " "

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## CHAPTER VII.

### Repairs and Renewals of Track.

THE repairs and renewals of track represent, in the long run, the wear and tear caused by trains moving over it, and damages from derailments, etc.; but it is impossible to make good the wear and tear as it occurs, and unless we can estimate the effect on the rails of the traffic passing over them, there is no way to ascertain to what extent they have deteriorated in any given period of time, or by any given train service, until they are worn out.

The only practical basis for estimating the deterioration of rails is by the weight which passes over them, or the gross ton mileage of engines, cars and contents of cars; and if we know how many gross ton miles passing over one mile of track, at an average speed, will wear it out, and what it costs to renew it, then we can determine what proportion of the life of the rails has been destroyed, and what proportion of the cost of renewing them is chargeable to any given volume of gross ton mileage which has passed over them. This is what we ought to know in order that we may charge as expenses an amount which represents as nearly as possible the actual depreciation of track for the period of time covered by the gross ton mileage.

We have seen in Chapter IV. that the expenditure of $1,018,660 for the maintenance of track in ten years was abnormal, in that it included the renewal of the old rails, which were in the track at the beginning of that period.

The cost of new rails and joint fastenings for the period stated was $718,931, and for current repairs, including spikes, frogs, switches, labor and tools $299,729, both of which together represent the expenditures in ten years, to make good previous deterioration, as well as the wear and tear due to 1,831,523,358 gross ton miles of revenue trains during that period.

At the beginning of this period there were 189 miles of iron rails in the track, of various patterns and weights, all of which were renewed within seven years. Renewals for the first two years were made with 58-pound iron rails, none of which remained in the track at the expiration of the ten years. For the next two years about one-half of the renewals were with 60-pound iron rails, and the other

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half with 60-pound steel rails, after which all renewals were with 60-pound steel rails.

The number of miles of each class of rails in service during the period of ten years, and the gross tonnage of revenue trains which passed over them, was as follows:

| | Miles in service per annum. | Average gross tons per mile per annum. | Total gross tonnage in ten years. |
|---|---|---|---|
| Old iron rails, | 189.00 | 2,445,570 | 462,212,655 |
| 58-lb. iron rails, | 32.81 | 6,591,612 | 216,270,790 |
| 60-lb. iron rails, | 28.94 | 8,191,357 | 237,057,882 |
| 60-lb. steel rails, | 160.06 | 5,722,741 | 915,982,031 |
| Total, | 410.81 | 4,458,330 | 1,831,523,358 |

The cost of the 32.81 miles of 58-pound iron rails and joint fastenings was $104,934.98, or $3,198.26 per mile, and when 216,270,790 gross ton miles of revenue trains had passed over them, they were taken up as unfit for further use in the main track, and the best rails were used to repair sidings. The cost per gross ton mile of revenue trains for these rails was 0.4852020 mills.

The cost of 28.94 miles of 60-pound iron rails and joint fastenings was $74,891.39, or at the rate of $2,587.82 per mile, and the gross tonnage of revenue trains which passed over each mile of these rails in eight of the ten years was 8,191,357 ton miles, but they were not entirely worn out in that period, and the additional tonnage that they were capable of carrying was about 2,309,034 ton miles per mile of track, or one and a half years longer service with the gross tonnage as of the tenth year. This makes the life of the 60-pound iron rails equivalent to 10,500,491 gross ton miles, and their cost per gross ton mile of revenue trains was 0.2464475 mills.

The cost of the 160.06 miles of 60-pound steel rails was $539,103.96 over which 915,982,031 gross ton miles of revenue trains had passed; but as it would require at least 40,000,000 gross ton miles to wear out one mile of such rails, and only 5,722,741 ton miles per mile of road had passed over them, they had depreciated $77,128.89 or about 14.3 per cent. of their value, making the cost per gross ton mile of revenue trains 0.0842035 mills.

We do not know the original cost of the old iron rails, or the tonnage which

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had passed over them prior to the ten years, but putting them on a par with the 58-pound iron rails, we have for the depreciation in value of rails during the ten years:

| | Gross ton miles. | | Mills. | Dollars. |
|---|---|---|---|---|
| Old iron rails, | 462,212,655 | at | 0.4852020 | $224,266.50 |
| 58-lb. iron rails, | 216,270,690 | " | 0.4852020 | 104,934.98 |
| 60-lb. iron rails, | 237,057,882 | " | 0.2464475 | 58,422.32 |
| 60-lb. steel rails, | 915,982,031 | " | 0.0842035 | 77,128.89 |
| Total depreciation for, | 1,831,523,358 | " | 0.25375198 | $464,752.69 |
| Betterments in ten years, | | | | 254,177.64 |
| Total expended on rails and joint fastenings, | | | | $718,930.33 |

The depreciation in value per ton per annum, of course, depends upon the density of the traffic, as well as the cost and endurance of the rails. For the different classes of rails on this 189 miles of road it was as follows:

| | Depreciation per ton. | Average years. | Depreciation per ton per annum. |
|---|---|---|---|
| 58-lb. iron rails, | $35.09 | 7.10 | $4.94 |
| 60-lb. iron rails, | 21.41 | 7.10 | 3.01 |
| 60-lb. steel rails, | 5.11 | 4.45 | 1.14 |

NOTE.—Some railroad accountants estimate the depreciation of steel rails at one dollar per ton per annum, but this is mere guess-work unless the gross tonnage is known, for at the present cost of renewing 60-lb. steel rails (of, say, $16.00 per ton) it would require a gross tonnage of 2,500,000 ton miles per mile of road per annum to make such a depreciation, and the majority of railroads have either more or less than that amount of gross tonnage.

This, however, was not all that it cost to keep up the track during the ten years, for there was an expenditure of $105,051.12 for frogs and switches, spikes and track tools, and $194,678.26 for labor, making a total of $299,729.38 for repairs of track, which was at the rate of 0.163650 mills per gross ton mile of revenue trains. This cost per gross ton mile was not uniform for the whole period of ten years, being heaviest for the years in which a large part of the old iron rails were being renewed, much lighter for the eighth and ninth years, when all the old rails had been replaced, and lightest for the tenth year, when nearly 80 per cent. of the rails were steel.

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## REPAIRS OF TRACK.

| | Gross tonnage. | | Cost. | Per gross ton mile—mills. |
|---|---|---|---|---|
| First year, | 95,751,392 | .... | $28,787.82 | .... 0.300652 |
| Second year, | 92,479,597 | .... | 25,476.01 | .... 0.275477 |
| Third year, | 104,778,786 | .... | 28,926.99 | .... 0.276077 |
| Fourth year, | 117,785,203 | .... | 30,477.63 | .... 0.258756 |
| Fifth year, | 165,801,244 | .... | 34,994.60 | .... 0.211064 |
| Sixth year, | 198,698,791 | .... | 28,612.84 | .... 0.144001 |
| Seventh year, | 224,222,029 | .... | 44,246.34 | .... 0.197333 |
| Eighth year, | 261,539,542 | .... | 38,707.27 | .... 0.147998 |
| Ninth year, | 279,527,411 | .... | 23,033.73 | .... 0.082402 |
| Tenth year, | 290,939,363 | .... | 16,496.15 | .... 0.056699 |
| Total, | 1,831,523,358 | .... | $299,729.38 | .... 0.163650 |

## TOTAL COST OF MAINTENANCE OF TRACK.

### Per Gross Ton Mile.

| | Mills. | |
|---|---|---|
| General average for ten years: | | |
| Renewals, | 0.253752 | |
| Repairs, | 0.163650 | |
| | | 0.417402 |
| With 60-pound steel rails: | | |
| Renewals, | 0.084203 | |
| Repairs, | 0.056699 | |
| | | 0.140902 |

### Heavier Rail Sections.

To what extent the endurance of steel rails is increased by adding to their weight we do not know, but we do know that the very heavy locomotives and cars now in use concentrate more weight on each wheel, which, with the higher speed at which trains are run, must increase the wear of rails per gross ton mile of trains passing over them. It is claimed that 90-pound steel rails have withstood a service of 60,000,000 of gross ton miles per mile of track, which, as compared with 40,000,000 for 60-pound steel rails, would be in proportion to their increased weight.

### Cost in Proportion to Speed.

In the above analysis of renewal of rails and repairs of track, we have taken into consideration the gross ton mileage of revenue trains only, omitting that

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resulting from the engine and car mileage of work trains and switching service, but in distributing the cost of maintenance and renewal of track to passenger and freight trains (in Chapter IV.) all of the gross ton mileage was taken into account.

It was assumed that the wear and tear of tracks by the different classes of trains is in proportion to their weight and speed, or their relative gross ton mileage, at a speed of one mile per hour. The ascertained gross ton mileage of work trains, at an equivalent speed of one mile per hour was to some extent estimated and divided between passenger and freight service, in proportion to the weight and speed of passenger and freight trains. Account was kept of the mileage of engines switching for passenger and freight service on the usual basis, from which the gross ton mileage of switching engines was ascertained, but the gross tonnage of cars switched was estimated monthly. In order to show how much of the gross tonnage was ascertained by accounts kept of weight and distance, and how much was estimated in part, the figures are given as follows:

| Trains. | Gross ton miles. | Speed. | Equivalent gross ton miles at one mile per hour. |
|---|---|---|---|
| Passenger, | 434,798,095 | 25.52 | 11,531,729,173 |
| Freight, | 1,396,725,263 | 16.29 | 22,746,956,498 |
| Work, | 84,055,621 | 11.86 | 996,615,024 |
| Switching Passenger, | 12,566,408 | 5.9 | 74,141,208 |
| Switching Freight, | 103,437,216 | 5.6 | 577,706,516 |
| Total, | 2,031,582,603 | 17.68 | 35,927,148,419 |

The gross ton miles at one mile per hour, which resulted from switching passenger and freight was charged to each respectively, and the gross ton miles of work trains was divided proportionately between passenger and freight monthly, making the distribution between passenger and freight at equivalent speed as follows:

| | | | |
|---|---|---|---|
| Passenger, | 11,531,729,173 | | |
| Switching, | 74,141,208 | | |
| Work trains, | 362,071,469 | 11,967,941,850 | 33.31% |
| Freight trains, | 22,746,956,498 | | |
| Switching, | 577,706,516 | | |
| Work trains, | 634,543,555 | 23,959,206,569 | 66.69% |
| Total, | | 35,927,148,419 | 100.00% |

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While the average speed at which the total gross tonnage was moved was 17.68 miles per hour, the equivalent speed for revenue trains to include switching and work trains, and make the total of 35,927,148,419 gross ton miles, at one mile per hour, was 19.616 miles per hour, and the relative speed of passenger and freight gross ton miles was as follows:

Passenger, .....27.526 miles per hour.
Freight, .....17.154 miles per hour.

We can differentiate the cost of repairs and renewals of track for different speeds with 60-pound steel rails as follows:

| | Miles per hour. | Per gross ton mile—mills. |
|---|---|---|
| Speed, ..... | 19.616 ..... | 0.140902 |
| " ..... | 10 ..... | 0.071830 |
| " ..... | 20 ..... | 0.143660 |
| " ..... | 30 ..... | 0.215490 |
| " ..... | 40 ..... | 0.287320 |
| " ..... | 50 ..... | 0.359150 |

NOTE.—The cost of renewals is on the basis of $35.70 per ton as the net cost of steel rails and joint-fastenings, after crediting the amount realized from the sale of the old iron rails taken up.

It has been claimed that the wear of rails increases in a greater ratio than the speed, and it might be assumed that the wear of rails increases in proportion to resistance due to speed, instead of directly as the speed.

In the absence of exact data it is safer to assume that the wear of rails increases directly in proportion to the increase of speed, which is the basis of the above distribution of the cost of maintenance of track between passenger and freight service.

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## CHAPTER VIII.

### Estimating the Cost of Transportation under Different Circumstances and Conditions.

THE better a railway manager is informed as to what each class of service should cost, the easier it will be to discern where any possible saving in expenses can be made, and the more conveniently expenses are grouped for comparison, the more readily he can see and correct errors in the previous conduct of the business.

It was for the purpose of facilitating comparisons that the grouping of expenses, shown in Chapter IV., was the first used, instead of mixing up parts of train, car and gross tonnage expenses with station expenses and others, under one general heading, in utter disregard of the principle that no comparison can be made between dissimilar things except as to their dissimilarity.

If the operating expenses increased, it was desirable to know why, and this could be ascertained only by comparing them with the service performed, to do which there must be a unit of measure for the service, such as the dollar is for the expenses; but there is no absolute unit of service in the operation of a railway, and therefore no basis for comparing its expenses in the aggregate, for which reason both service and expenses must be subdivided into at least as many classes as there are different kinds of service. It is customary to subdivide the expenses into many more classes than the service can be divided, and then group them under general headings to facilitate comparison; but unless they are grouped with reference to the classes of service performed it does not facilitate comparison.

### Estimating Cost of Passenger Trains.

In view of the oft-recurring demand of the travelling public for additional passenger trains, it is important to know, as nearly as practicable, what it costs per mile to run such trains. This will depend primarily upon the weight of the train, its speed, and the number of cars of which it is composed. Take, for instance, a light train of three cars, with a total weight of 160 tons, at 30 miles per hour, and we have as its cost, on the road we have been considering, after its track had been laid with 60-pound steel rails—

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| | | |
|---|---|---|
| *Train expenses per train mile, | 14.08 | cents. |
| *Car expenses 3-car miles at 2.412 cents, | 7.24 | " |
| *Fuel and water 160 ton miles at 0.049444, | 7.91 | " |
| †Maintenance of track 160 ton miles at 0.021549, | 3.45 | " |
| Total running expenses per train mile, | 32.68 | " |

This would provide the minimum accommodation for a day run with an average of 20 passengers per train mile, and light mail and express. The estimated cost of the train is exclusive of terminal and fixed expenses.

For a train of five cars weighing 280 tons at 40 miles per hour, the probable cost would be—

| | | |
|---|---|---|
| *Train expenses per train mile, | 14.08 | cents. |
| *Car expenses 5-car miles at 2.412 cents, | 12.06 | " |
| *Fuel and water 280 ton miles at 0.049444, | 13.84 | " |
| †Maintenance of track 280 ton miles at 0.028732, | 8.04 | " |
| Total running expenses per train mile, | 48.02 | " |

This would provide accommodation, on a day run, for an average of 30 passengers per train mile, with a 50-foot postal car and space for a light express business. The estimated cost of this train is also exclusive of terminals and fixed expenses.

For an express train of seven cars (vestibuled) including two sleepers, which would weigh 425 tons, at a speed of 40 miles per hour, the probable cost would be—

| | | |
|---|---|---|
| *Train expenses per train mile, | 14.08 | cents. |
| *Car expenses 5-car miles at 2.412 cents, | 12.06 | " |
| *Car expenses 2-car miles at 3.667 cents, | 7.33 | " |
| *Fuel and water 425 ton miles, 0.049444, | 21.01 | " |
| †Maintenance of track 425 ton miles at 0.028732, | 12.22 | " |
| Total running expenses per train mile, | 66.70 | " |

This train would provide full accommodation for an average of at least 40 passengers per train mile, with a 60-foot postal car, and a 60-foot car for express. The estimated cost of this train is exclusive of terminal and fixed expenses.

* Chapter IV. † Chapter VII.

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To ascertain the terminal expenses per train mile we must know the number of passengers on each train, which we will estimate as follows:

The first train would probably carry only local passengers, who travel an average distance of 40 miles, and it would require 50 passengers to make an average of 20 per train mile for every 100 miles run by the train.

The second train would accommodate the same local travel of 20 passengers per train mile, and, in addition thereto, it would require 10 through passengers to make an average of 30 per train mile for every 100 miles run by the train.

The third train would require 20 through passengers, in addition to 20 local, per train mile, making a total of 70 passengers for every 100 miles run by the train.

The ordinary terminal expenses on the road we have been considering were 12.07 cents per passenger, and on this basis we have, for the three trains—

| | Number of passengers. | Terminal expenses per train mile. |
|---|---|---|
| First train, | 50 at 12.07 cents. | 6.03 cents. |
| Second train, | 60 " | 7.24 " |
| Third train, | 70 " | 8.45 " |

We have seen that, with a density of gross tonnage of 969.060 ton miles per mile of road per annum, the tolls necessary to pay fixed expenses were 0.084129 of one cent per gross ton mile, which, for the above trains, would be—

| | | |
|---|---|---|
| First train, | 160 tons | 13.46 cents per train mile. |
| Second train, | 280 " | 23.56 " " |
| Third train, | 425 " | 35.75 " " |

Adding these terminal and fixed expenses to the running expenses per train mile ascertained above, we have, as the total cost per train mile and per car mile of each train—

| | Per train mile. Cents. | Per car mile. Cents. |
|---|---|---|
| Train of 3 cars, 32.68 + 6.03 + 13.46, | 52.17 | 17.39 |
| " 5 cars, 48.02 + 7.24 + 23.56, | 78.82 | 15.76 |
| " 7 cars, 66.70 + 8.45 + 35.75, | 110.90 | 15.84 |

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On the first train of three cars at least two would be for passengers and their baggage, on the train of five cars, 3½ cars, and on the train of seven cars, 5 cars. We have, therefore, as the approximate cost of transporting passengers and their baggage—

| | Per train mile. Cents. | | Per passenger mile—cents. |
|---|---|---|---|
| On train of 3 cars, 2 for passengers, | 34.78 | .... | 1.739 |
| " 5 cars, 3½ for passengers, | 55.16 | .... | 1.839 |
| " 7 cars, 5 for passengers, | 79.20 | .... | 1.980 |

## Estimated Cost of Freight Trains.

With the above results before them, the management of the road we have been considering could not fail to see that a great saving could be effected by the use of heavier locomotives for freight. In fact, attention had some years before been officially called to the necessity for an entire renewal of rails, so as to admit of the use of heavier locomotives; and with the improvement in track, the time had come when it was practicable to use "consolidation" engines, weighing from 50 to 60 tons, instead of eight-wheel and ten-wheel engines, which weighed from 35 to 40 tons.

Such an increase in the efficiency of locomotives would make it practicable to increase the average load of general tonnage trains from 87.85 to 146 tons, and thus reduce the train mileage for the same volume of tonnage 40 per cent. by increasing the average number of cars per train from 17.2 to 28.5, and making the average weight of trains 518 tons instead of 321 tons, in which case the comparative cost of the two trains, at 20 miles per hour, would be, per train mile—

| | 321 ton train. | | 518 ton train. | |
|---|---|---|---|---|
| *Train expenses, 1 train mile, | 24.19 | | | 24.19 |
| *Car expenses, 17.2 car mile, 0.72559 | 12.48 | 28.5 | at 0.72559 | 20.68 |
| *Fuel and water, 321 ton miles, 0.040624 | 13.04 | 518 | " 0.040624 | 21.04 |
| †Maintenance of track, 321 ton miles, 0.014366 | 4.61 | 518 | " 0.014366 | 7.44 |
| Total running expenses, | 54.32 | | | 73.35 |

* Chapter IV. † Chapter VII., page 48.

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As it would require five of the lighter trains to move the same number of cars and the same revenue tonnage as three of the heavier trains, the relative cost of movement would be—

| | | |
|---|---|---|
| With 321 ton train, | $5 \times 54.32 = 271.60$ | cents. |
| With 518 ton train, | $3 \times 73.35 = 220.05$ | " |
| Saving 19.0 per cent., | 51.65 | " |

Heavier locomotives would thus reduce the cost of movement 19 per cent., but increased capacity of cars, it was seen, would be a still greater economy; for if the average loads of cars were increased, without a proportional increase in their weight, the ratio of paying load to the total weight of trains would be increased. With this end in view careful attention had for some years been paid to the designs for both trucks and car bodies, with the result that, by the time the track was relaid with 60-pound steel rails, a large proportion of the freight cars were of what was then the maximum capacity of 60,000 pounds, and of increased capacity for freight in bulk, and the average car load of freight was doubled, with an addition of about 25 per cent. to the average weight of cars. The new standard cars, with double the former loads, would weigh 23 tons each, and with 20 per cent. running empty, the average weight of cars and loads would be about 21 tons; and a train of 20 cars, with loads of 8.16 tons, would give a paying load of 163 tons out of a total weight of 500 tons, including weight of engine and tender, the cost of running which, at 20 miles per hour, would be, per train mile—

| | | |
|---|---|---|
| *Train expenses per train mile, | 24.19 | cents. |
| *Car expenses, 20 car miles at 0.72559 cents, | 14.51 | " |
| *Fuel and water 500 ton miles at 0.040624 cents, | 20.31 | " |
| †Maintenance of track 500 ton miles at 0.014366 cents, | 7.18 | " |
| Total running expenses, | 66.19 | " |

As it would require only 20 of such 500 ton trains to move the same tonnage as 37 of the 321 ton trains, the relative cost of movement would be—

* Chapter IV. † Chapter VII., page 48.

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| | | |
|---|---|---|
| 321 ton train, | 54.32 × 37 = 2009.84 | cents. |
| 500 ton train, | 66.19 × 20 = 1323.80 | " |
| Saving 34 per cent., | 686.04 | " |

Consolidation engines of from 50 to 60 tons are no longer the standard of greatest efficiency in freight locomotives, the most recent development in locomotive building being a "Decapod" weighing 130 tons, with tractive power of over 57,000 pounds.

The size and capacity of freight cars has also been further increased, and average car loads of 14 tons are not exceptional. The average weight of the modern freight cars is not so easy to ascertain, but it is probably about 15 tons.

The "Decapod," above alluded to, would haul over the road in question a train of 50 cars, the total weight of which, including engine and tender, would be 1,645 tons, the cost of running which, at 20 miles per hour, would be approximately—

| | | |
|---|---|---|
| *Train expenses per train mile, | 24.19 | cents. |
| *Car expenses 50 car miles at 0.72559 cents, | 36.28 | " |
| *Fuel and water 1645 ton miles at 0.040624 cents, | 66.83 | " |
| †Maintenance of track 1645 ton miles at 0.014366 cents, | 23.63 | " |
| Total running expenses, | 150.93 | " |

Since the small roads have been aggregated into large systems, it is a notable fact that the transportation of company's freight has largely increased, and it frequently amounts to as much as 15 per cent. of the total tonnage moved. The effect of this is to increase the non-paying load of freight trains, and with average car loads of 14 tons, about 12 are revenue tonnage. For this reason, and the probability of 20 per cent. of the cars being empty, the paying load of 1,645 ton trains would probably average 525 tons.

Such a train would carry six times as much tonnage as the actual load of the 321 ton train, and the relative cost of movement would be—

* Chapter IV. † Chapter VII., page 48.

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| | | |
|---|---|---|
| 321 ton train, | 54.32 × 6 = 325.92 | cents. |
| 1645 ton train, | 150.93 | " |
| Saving 53.7 per cent., | 174.99 | " |

Recapitulating the cost per train mile as estimated above, and deducing therefrom the cost per car mile and per ton mile of paying load, we have gradations in the cost of movement by improvements in equipment as follows:

| | Cost per train mile. Cents. | Cost per car mile. Cents. | Cost per ton mile. Cents. |
|---|---|---|---|
| 87.85 tons per train with 17.2 old cars, | 54.32 | 3.158 | 0.618 |
| 146.00 tons per train with 28.5 old cars, | 73.45 | 2.577 | 0.503 |
| 163.00 tons per train with 20 new cars, | 66.19 | 3.310 | 0.406 |
| 525.00 tons per train with 50 new cars, | 150.93 | 3.019 | 0.287 |

All of the preceding freight estimates are for the cost of movement only, and do not include terminal and fixed expenses, the cost of which depend upon the volume of the traffic and other conditions; terminal expenses per ton mile depending upon the number of tons handled, and fixed expenses per ton mile on the density of gross ton mileage, and the ratio of revenue tonnage to total gross tonnage.

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## CHAPTER IX.

### How Increased Traffic Decreases the Cost of Transportation.

IF we refer back to the expenses of maintenance and operation, as classified and distributed in Chapter IV., we find the relative proportions of the different classes of expenses chargeable to freight were as follows:

| | | | |
|---|---|---|---|
| Fixed expenses, | $1,175,052 | 25.95 | per cent. |
| Terminal and station expenses, | 647,191 | 14.29 | " |
| Train expenses, | 1,086,457 | 23.99 | " |
| Car expenses, | 542,263 | 11.98 | " |
| Gross tonnage expenses, exclusive of betterment to track, | 1,077,220 | 23.79 | " |
| Total, | $4,528,183 | 100.00 | " |

The fixed expenses being such as are not influenced appreciably by increase in traffic, it stands to reason that 25.95 per cent. of the total expenses chargeable to freight would remain practically the same if the freight traffic were doubled.

If twice the number of tons of freight were handled, 14.29 per cent. of the expenses would be increased, but not necessarily in the same ratio, for increased volume of freight to some extent decreases the cost per ton of handling it.

If double the revenue tonnage were moved by each train without increasing the car loads, there would be no increase in fixed and train expenses; but car expenses, and possibly terminal expenses, would be doubled, while gross tonnage expenses would be increased in proportion to the increase in revenue tonnage and increased weight of locomotives. In the case before us it would involve an increase in gross ton mileage, and consequently in the gross tonnage expenses, of about 80 per cent., making a possible addition to total freight expenses—

| | | |
|---|---|---|
| For terminal and station expenses, | 14.29 | per cent. |
| For car expenses, | 11.98 | " |
| For gross tonnage expenses, | 19.03 | " |
| Total, | 45.20 | " |

If the train loads were doubled, by doubling the load of each car, there would be no appreciable increase in fixed train and car expenses, but to do this locomo-

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tives and cars must be heavier, which, with the increase in revenue tonnage, would add about 45 per cent. to the gross ton mileage, making a probable addition to total freight expenses—

| | | |
|---|---|---|
| For terminal and station expenses, | 14.29 | per cent. |
| For gross tonnage expenses, | 10.71 | " |
| Total, | 25.00 | " |

It will be seen, therefore, that it was practicable to double the revenue tonnage with an addition of from 25 to 45 per cent. to the cost of the freight service.

In the case of passenger trains, the fixed expenses, train expenses, and to a great extent the gross tonnage expenses, are little influenced by the paying load. It is primarily the number of passenger trains that determine the cost of the service, and additional cars can be added at comparatively small cost, but ordinary terminal expenses should increase very nearly in proportion to the number of passengers ticketed.

When traffic is light, it may not suffice to make full train loads at such frequent intervals as it is necessary to run trains to accommodate trade and travel, for a certain number of trains must be run, whether there are full loads for them or not; and even if there are full loads in one direction they may be comparatively light in the other direction.

Trains must be run in both directions, even if they are empty one way; and thus it happens that additional traffic, which requires no additional trains to accommodate it, can often be carried at very low rates with a reasonable profit; and this makes additional traffic at minimum rates desirable, provided it can be secured without any reduction in the regular rates for traffic already controlled.

The facilities afforded by railways, develop trade and travel in the region traversed by them, and as traffic increases, the train loads are increased with but little addition to the cost of operation. When additional trains become necessary, they increase only a part of the expenses, and thus it happens that increased volume of traffic naturally decreases the cost of transportation.

The consolidation of railways has been to some extent a factor in the reduction of the cost of operation, for it completes and makes more effective the combination of railways into through lines, which reach out beyond the territorial limits

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of a single road, and secure from a distance additional traffic, which is carried at a minimum cost for the reasons already stated. It was claimed, and no doubt confidently expected, that in combining a number of roads into a single system a large saving would be made in the expenses of administration, but this expectation has not been realized, for while consolidation has reduced the number of employees at junction points, and perhaps to some extent elsewhere, it has generally resulted in the multiplication of departments and bureaus, in charge of officials with high pay, and general officers at salaries formerly unheard of, to say nothing of additional clerks and attendants in the enlarged general offices of the system, more expensive office accommodations, and largely increased consumption of stationery and other supplies.

There is necessarily a limit to the increase in train loads, which varies according to the characteristics of the road, as originally constructed. This has led to the reconstruction in part of many roads, and maximum grades have been reduced and lines straightened to increase the efficiency of the motive power. Heavier locomotives have been adopted, and the types changed to increase their tractive power, thus still further increasing their efficiency; but locomotives of greater capacity weigh more, and necessitate heavier rails and the strengthening of bridges and other structures. The extent to which these improvements to the roadway and track can be carried as a measure of economy, depends on the outlay of capital which the volume of traffic will justify. If economy in operation has been taken into consideration in the original construction of the road, there is little room for improvement afterwards, and hence the importance of a careful location, and a proper standard of construction, of which more will be said in a subsequent chapter.

After all has been done to secure the greatest efficiency of motive power, and make possible the movement of heavy trains, much depends upon the efforts of the operating department to keep the train and car mileage down to the minimum requirements of the traffic. Constant watchfulness is necessary to do this, and the importance of having accurate statistics of the results of operation at frequent intervals, to enable operating officers to see what they are doing cannot be overestimated.

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## CHAPTER X.

### The Proper Utilization of Motive Power.

In the early days of railways it was the custom to assign an engineer to each locomotive, and regulate the daily service of the machine by the number of hours which constituted a day's work for a man, with occasional exceptions when urgent demand for Motive Power made it necessary to tax the endurance of the engineer and his fireman beyond the usual limit. So long as the engineer was available, he alone was permitted to run his engine, and when it went into the shops for repairs, he was generally employed in its renovation, for engineers were, as a rule, competent machinists, and at home either on the "footboard" or in the shop.

There were undoubtedly some advantages in this arrangement, but there were at least two manifest disadvantages:

*First.* The mileage of locomotives being thus limited, the interest on their cost was greater than necessary, in proportion to the service performed by them annually.

*Second.* Their life was prolonged beyond the period of their usefulness, to such an extent that they became antiquated long before they were retired from service.

In 1875 there came on the road above referred to a sudden demand for a large increase in its Motive Power, without adequate means to provide it, except by increasing the mileage of the locomotives already in service far beyond the endurance of single crews; and it became necessary to try the experiment of increasing the length of the engine runs. Engines that had formerly been run 140 miles per day were given a straight run of 280 miles, and doubled back before they had time to cool off; and so far from being dissatisfied with the result, the length of the engine runs was increased subsequently as occasion required.

It was anticipated that the cost of repairs of locomotives per mile run would be increased by changing crews, and to minimize this, what are now known as "Travelling Engineers" (but were then called "Road Foremen of Engines"), were charged with the duty of frequent inspections on the road. The result was an

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agreeable surprise, for the cost of repairs of locomotives which made long runs and changed crews was less than for such as had their own special crews. The average cost of repairs of 17 locomotives so used running 38,556 miles per annum for four or five consecutive years, is shown in the following statement, and speaks for itself, when compared with the general average of 3.44 cents per mile for seven previous years.

STATEMENT SHOWING THE SERVICE AND COST OF REPAIRS OF SEVENTEEN TEN-WHEEL FREIGHT ENGINES.

| | Service. | | | Cost of Repairs. | |
|---|---|---|---|---|---|
| Nos. | Months. | Miles run. | Miles per month. | Amount. | Per mile—cents |
| 1 | 71 | 197,986 | 2,788 | $6,415.35 | 3.240 |
| 2 | 71 | 225,537 | 3,176 | 4,930.57 | 2.186 |
| 3 | 62 | 212,419 | 3,426 | 3,642.65 | 1.715 |
| 4 | 62 | 190,960 | 3,080 | 4,557.71 | 2.387 |
| 5 | 62 | 188,622 | 3,042 | 4,373.35 | 2.319 |
| 6 | 61 | 193,341 | 3,170 | 5,399.15 | 2.793 |
| 7 | 61 | 182,439 | 2,991 | 4,834.21 | 2.647* |
| 8 | 61 | 186,857 | 3,063 | 3,868.90 | 2,070 |
| 9 | 56 | 188,086 | 3,358 | 3,385.67 | 1.800 |
| 10 | 56 | 175,631 | 3,136 | 2,660.33 | 1.514 |
| 11 | 55 | 167,283 | 3,042 | 4,190.23 | 2.505 |
| 12 | 55 | 163,352 | 2,970 | 4,586.86 | 2.808 |
| 13 | 55 | 184,577 | 3,356 | 4,543.54 | 2.461 |
| 14 | 54 | 190,586 | 3,529 | 3,198.06 | 1.678 |
| 15 | 54 | 179,973 | 3,333 | 3,259.56 | 1.811 |
| 16 | 37 | 143,236 | 3,871 | 2,279.20 | 1.591 |
| 17 | 37 | 145,825 | 3.941 | 3,175.36 | 2.177 |
| Averages, | | | 3,213 | | 2.223 |

* Includes heavy damage by accident.

This is believed to have been the first experiment in changing crews, but since that time it has become quite common to increase the mileage of locomotives by several different methods of changing crews.

*First.* To have a regular crew for each locomotive, but also to have a number of extra crews, which have no locomotives assigned to them, but take out those

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of regular crews during the interval allowed for rest, and in cases of sickness or other disability.

*Second.* To have two or three regular crews assigned to one locomotive on certain runs, according to the ability of the locomotive to make double or triple the mileage of a single crew.

*Third.* To assign three or more crews to certain runs, and give them the number of locomotives necessary to perform the same service, whether it be two or more.

*Fourth.* To group together all the crews required for freight service, and all the crews required for passenger service, or all required for both freight and passenger service, and let them take the locomotives alternately in regular order.

By the second method each crew always gets the same locomotive, and by the other three methods they do not. The fourth method, which is now called "pooling," is the one by which the above results were obtained, and seems to have been successful wherever it has been inaugurated, with proper precautions against the careless handling of engines, which may occur by reason of the difficulty in fixing responsibility on any one crew. There has been much discussion of the "pooling" system, which would be out of place here, the intention of the writer being to give only his own practice, and the reasons therefor, with due respect for the views of others.

The same results practically can be obtained by the use of extra crews as by pooling, for by either method the mileage of locomotives can be increased in any desired proportion to meet the fluctuating demands of traffic; but "pooling" seems more equitable to the men than the use of extra crews, in that it puts all of them on an equality as regards service and pay, while extra crews are allowed to do only such service as the regular crews cannot perform, and are paid accordingly, which often gives them light work and small pay, while the regular crews are getting all the work they can do at full pay. The other two methods equalize the work and pay, but admit of no adjustment of the runs to meet fluctuations in traffic, for certain engines and certain crews must be kept together on the same runs, in order to effect the purpose of always giving each crew the same engine, although the engines are handled by two or more crews in succession.

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## CHAPTER XI.

### Efficient Handling of Cars and Estimating Freight Equipment.

WE have considered economy in operation as the result of increased density of traffic, which affords the tonnage for heavier train loads, and greater efficiency in Motive Power which makes it practicable to haul heavier trains, either with or without additional car mileage; but we must not overlook the fact that there is a limit to the earning capacity of a single car, which depends upon its average mileage per annum, as well as the average loads it carries, and consequently, the greater the average mileage of freight cars, the greater should be the earnings per car per annum.

The preponderance of traffic in one direction makes it necessary that cars shall be moved empty as well as loaded, and unless the movement of empties receives the same careful attention as is given to the prompt dispatch of loaded cars, the best results cannot be obtained, for there is no use in having freight to haul if the cars in which to haul it are not supplied when and where they are needed. It is very desirable to increase the average freight train load, but if the prompt movement of empties is neglected, by giving all the preference to loaded cars, it may result in loss of revenue, and will certainly reduce the average mileage per freight car. There is an old saying, that "Cars earn money only while their wheels are turning," which is applicable to empties as well as loaded cars; for empty car mileage is as necessary to accommodate the traffic as the movement of loaded cars, unless the tonnage is always the same in both directions, which very rarely happens.

If the Motive Power of a railway is sufficient to haul the tonnage offered, it necessarily follows that it is sufficient to haul the empties back for reloading; but if the Motive Power is not properly distributed to meet the demands of traffic, the tonnage may be congested for want of power on one part of a large system, while there is a surplus elsewhere.

Competition for freight is often the cause of failure to move empties from points where they are not needed immediately, to points where loads are waiting for them. It is easier to hold empties when freight is promised in a day or two, than to risk the chance of losing such freight by failure to get more by the time

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they will be needed, in which case the cars are not placed for loading until wanted; and in like manner, loaded cars are held in yards before delivery for unloading, thus lying idle without even a claim for demurrage charges. Competition also prevents the collection of demurrage charges which have been assessed for the detention of cars placed either for loading or unloading.

The great difference in car load and less than car load rates gives a margin for freight brokerage, and induces the aggregation of a number of small consignments into a car load, which is shipped "to order," with a draft for the value of the consignment attached to the bill of lading, necessitating the holding of the cars until the agent for the consignees collects the money from them, pays the draft, gets the bill of lading and presents it. In such cases there should be, and probably there is, a demurrage charge, but that is scant pay for the loss of mileage, while the cars are being used as a warehouse, to say nothing of the loss in revenue by evasion of the rates on less than car load shipments, by their conversion into car loads. The obvious remedies for such difficulties as I have noted are:

*First.* The careful and intelligent direction of the daily movement and distribution of empties to meet the requirements of traffic.

*Second.* A sufficiency of Motive Power, and the proper distribution of it to meet the varying demands as they occur.

*Third.* The making and enforcement of proper rules to prevent the unnecessary detention of cars, made effective by the invariable collection of demurrage charges, which are at least high enough to stimulate shippers and consignees to expedite the release of cars.

The proper handling of cars is a matter for daily and hourly attention, the results of which should appear in the records of car movement; and the more in detail such records are kept, and the more promptly the results can be shown the better.

We have seen that average car loads were small on the road we have been considering, which was largely due to the preponderance of traffic in one direction, not only the annual excess of tonnage one way, but for shorter periods, sometimes in one direction and sometimes in the other, necessitating a much larger mileage of empties than the annual excess one way would indicate. This disadvantage

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was, however, compensated for, in part at least, by what would now be considered an extraordinary average mileage per car, an exhibit of which will be useful for comparison with the average freight car mileage of the present time, which is so small as to force itself on the attention of railway managers.

AVERAGE NUMBER OF CARS IN SERVICE FOR TEN YEARS.

| | | |
|---|---|---|
| Box and stock cars, | 818.3 | |
| Flats and gondolas, | 268.9 | |
| Total, | 1087.2 | |

CLASSIFIED MILEAGE INCLUDING FOREIGN CARS.

| | | |
|---|---|---|
| Box and stock cars, | 110,667,214 | |
| Flats and gondolas, | 12,641,900 | |
| | | 123,309,114 |

UNCLASSIFIED MILEAGE OF CARS OWNED.

| | | |
|---|---|---|
| Reported by foreign roads, | 69,358,248 | |
| Home mileage not classified, | 155,536 | |
| | | 69,513,784 |
| Total car mileage, | | 192,822,898 |
| Deduct mileage of foreign cars, | | 27,834,126 |
| Total car mileage by cars of 189 miles of road, | | 164,988,772 |
| Average mileage per freight car owned per annum at home and on foreign roads, | | 15,176 |

Assuming that the unclassified mileage included the same proportion of each class of cars as that which was classified, we have—

| | | |
|---|---|---|
| 1087.2 box and stock cars, | 148,073,790 | miles. |
| 268.9 flats and gondolas, | 16,914,982 | " |
| | 164,988,772 | " |
| Box and stock cars each per annum, | 18,095 | " |
| Flats and gondolas each per annum, | 6,328 | " |

This mileage was made on revenue trains, and additional mileage was made by flats and gondolas in road service, which is not taken into this account.

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### Estimating Freight Equipment.

The freight equipment required to meet the demands of traffic depends upon the density of the freight traffic, the average mileage per car per annum, and the average load per car. Thus, with a density of 300,000 ton miles per mile of road per annum, average loads of ten tons per car, and an average of 15,176 miles per car per annum as above, two freight cars per mile of road would suffice, unless the interchange of cars with foreign roads necessitated the ownership of cars in excess of home requirements, for $\frac{300,000}{10 \times 15,176} = 1.98$ cars per mile of road.

If, however, a larger proportion of flats and gondolas was required than above, more cars would be needed, on account of the smaller average mileage made by such cars, in which case we would divide the density of traffic to be carried by each class of cars, by their annual carrying capacity, which is their average loads multiplied by their average mileage per annum, as, for instance, if one-half of a total tonnage of 300,000 ton miles was to be carried in box cars with nine ton loads, and the other half on flats and gondolas with eleven-ton loads, we would have—

Box cars per mile of road, . . . . . $\frac{150,000}{9 \times 18,095} = 0.921$

Flats and gondolas per mile of road, . . $\frac{150,000}{11 \times 6,328} = 2.155$

Total cars per mile of road, . . . . . 3.076

In like manner, the number miles of road for which one freight locomotive is required may be estimated by multiplying the average mileage per locomotive per annum by the average train load, and dividing the product by the density of the freight traffic, as, for instance, with an average of 36,000 miles per annum for freight locomotives, average train loads of 150 tons, and density of freight traffic as above, $\frac{36,000 \times 150}{300,000} = 18$, and one freight locomotive for every eighteen miles of road should suffice.

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## CHAPTER XII.

### The Relative Adjustment of Rates with Reference to the Cost of Transportation.

TRANSPORTATION by old methods was a commodity the value of which depended upon the natural law of supply and demand, and the conditions as regards transportation by railways differ only in one respect, which is that railway companies enjoy a monopoly in the use of highways, the right to construct and operate which, to the exclusion of other common carriers, is derived from the State, which exercises supervision and control over the railway in its relations to the public, and requires that its rates shall be just and reasonable, without discrimination as regards individuals or localities, except in so far as such discrimination may result from natural conditions or legitimate competition.

Reasonable rates include a fair profit on the cost of the service performed, and compensation for risks incurred, which makes it important that we should at least know the *relative* cost of the service under different circumstances and conditions, although we may not be able to determine the cost in any particular case except approximately.

All rates of transportation are for a specified weight or bulk, and distance; but carriers are practically the insurers of goods transported by them, and are entitled to compensation for the risk, so that the relative value of the goods, as well as their relative bulk, differentiates the rates of the carriers for the same weight carried the same distance.

The relations of bulk and value to weight should be taken into consideration in the classification of freight, and the rates can then be made in the same relative proportions for each class as regards weight and distance, but not at a uniform rate per ton per mile for all distances, for the cost of transportation is not in proportion to distance only; and this leads us to consider to what extent weight and distance influence the expenses of maintenance and operation.

*First.* *Fixed Expenses* do not depend upon either the weight of the trains or the distance they are run, but the traffic must pay them, and the most equitable method of apportioning them seems to be in proportion to the relative gross

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ton mileage resulting from each kind of traffic. This takes into account both weight and distance, and differentiates the cost per ton mile of freight according to the relative proportion of dead and paying load.

*Second.* *Terminal and Station Expenses* depend upon the weight of the freight, without regard to the distance it is hauled, and are necessarily less per ton mile for longer than for shorter hauls.

*Third.* *Train Expenses* depend upon the distance trains are run, and not on the distance the cars or their contents are hauled. The longer, therefore, the average haul of freight, in proportion to the distance run by the trains which carry it, the less the train expenses are per ton mile of freight.

*Fourth.* *Car Expenses* depend upon distance only (except in so far as the cost of repairs may be slightly influenced by the weight of their contents), and the heavier the loads they carry the less such expenses are per ton mile of freight.

*Fifth.* *Gross Tonnage Expenses* are proportionate to gross weight and distance, and the larger the proportion of paying loads the less they are per ton mile of freight.

From the foregoing it will be seen that none of the expenses of transporting freight are in proportion to the distance freight is hauled.

The average haul of freight is the resultant of a number of different hauls of car loads, and parts of car loads, on the same or different trains; and while there is no fixed relation between it and the train mileage, car mileage, or gross ton mileage, in all of which distance is a factor, it has a material influence on the average train loads, the average car loads, and the proportion of dead and paying load, which are factors in the cost of transportation.

To make this more clear I will state the following general propositions:

*First.* The shorter the average haul of a given number of tons of freight, the less ton mileage they produce, and the greater the cost of terminal and station expenses per ton mile of paying load.

*Second.* The shorter the average haul of the freight, in proportion to the distance run by trains which carry it, the less effective the train service in producing ton mileage, and the greater the train expenses per ton mile of paying load.

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*Third.* The shorter the average haul of parts of car loads, the lighter the average load per car, and the greater the car mileage and car expenses per ton mile of paying load.

*Fourth.* The shorter the average haul of freight in proportion to the distance run by trains which carry it, the greater the gross tonnage, and the gross tonnage expenses per ton mile of paying freight.

*Fifth.* The shorter the average haul of parts of car loads the lighter the average load per car and the greater the gross tonnage and gross tonnage expenses per ton mile of paying load.

To understand how the length of the haul affects the average train loads, car loads and gross tonnage, we must consider in detail how the local freight is distributed and collected.

Before the days of railways the markets at which the agricultural products of the country were sold, and the wants of farmers were supplied could be reached only by wagon transportation or interior navigation, and the first railways built merely took the place of these elementary transportation facilities. Local freight trains loaded at a terminal point distributed the freight as they progressed, taking on little or none at intermediate points, and arrived at the other terminus with their loads greatly depleted. On their return trip they started with very light loads gathering up the produce of the country, and accumulated a train load to be delivered at the terminus from which they originally started. The gradual distribution of train loads going one way and the gradual accumulation of them going in the other direction made the average haul of freight much less than the distance the trains were run, and reduced the average train loads far below the number of tons with which they began and ended their round trips. Approximately one-half of the train service was non-effective in producing ton mileage of freight, and it was therefore impracticable to make the rates for transportation in proportion to the weight of the freight and the distance it was hauled, without making the long haul rates excessive as compared with the short haul rates. This fact, no doubt, influenced the first adjustment of local rates, but we find economic principles which justify the charging of higher rates per ton mile for short than for longer distances.

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When traffic was almost exclusively local, the average haul of freight was seldom much more than one-half of the distance the trains were run, and sometimes less; but as industries developed and interior markets were opened for agricultural and other products, the local traffic, from being set in one direction, became diverse, so that when a train dropped some of its cars, or a part of their contents, there might be freight in car loads, or less than car loads, going in the same direction to replace it. This additional intermediate tonnage, being for comparatively short hauls, did not increase the ton mileage in proportion to the additional number of tons taken on, but it made both the train and car mileage more effective in the movement of freight.

We have, in the case of the road under consideration, two classes of general tonnage of comparatively long hauls, and three classes of special tonnage of very short hauls, the relative volume of which for ten years was as follows:

| | Tons. | Ton miles. | Av'ge haul. |
|---|---|---|---|
| General through tonnage, | 1,130,047 | 188,309,268 | 166.6 |
| General local tonnage, | 1,719,794 | 188,819,602 | 109.8 |
| Special coal tonnage, | 137,352 | 1,640,376 | 11.9 |
| Special stone tonnage, | 200,485 | 1,121,655 | 5.6 |
| Special switching tonnage, | 362,842 | 755,144 | 2.1 |
| Totals and average haul, | 3,550,520 | 380,646,045 | 107.2 |

The general tonnage trains were necessarily run over the whole length of the road, or 189 miles, and the average haul of the general tonnage, both through and local, was 132.3 miles, or 70 per cent. of the distance run by the trains which hauled it.

The average haul of the general local tonnage was the resultant of an infinite number of different lengths of hauls, and we have no means of determining the relative proportion of local freight hauled shorter or longer distances than the general average of 109.8 miles. The tonnage classed as "through," was not all between termini, part of it being through intermediate junction points, which made the average haul of this class of freight less than the distance between termini of 189 miles.

We have already shown (in Chapter V.) the cost of the "general tonnage," which includes both "through" and "local" freight, the average hauls of which

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were respectively 166.6 and 109.8 miles; and if we can determine the *relative* cost of the "through" and "local," it may serve to illustrate to what extent the cost of transporting freight is influenced by the length of the haul, even if we cannot ascertain the exact cost of each.

The relative number of trains, train miles, car miles, and gross ton miles of through and local tonnage was not recorded, but we have the aggregate number of trains and the total train mileage, car mileage and gross ton mileage, for the general tonnage for a period of ten years as follows:

| | |
|---|---|
| Number of trains, | 22,714 |
| " train miles, | 4,292,868 |
| " car miles, | 73,849,854 |
| " gross ton miles, | 1,378,623,884 |

The relative number of tons per train, and the average number of cars per train, may or may not have been the same for both through and local trains, and we have, therefore, four possible combinations that would affect the relative train mileage, car mileage and gross ton mileage:

*First.* With the same number of tons and the same average number of cars per train.

*Second.* With the same average number of cars but a different number of tons per train.

*Third.* With a different average number of cars, but the same number of tons per train.

*Fourth.* With a different number of tons and a different average number of cars per train.

If now we ascertain the relative cost of through and local freight service on these four combinations of the number of tons, and the average number of cars per train, we will have, within certain limits, the relative cost of the through and local freight, the average hauls of which are known.

In the first place, we must fix such limitations on the variation in train loads and average cars per train as could reasonably be considered possible; and in doing this we may assume that, with an average train load of 125 tons, the local

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trains could not have handled more than 135 tons per train, in which case the through trains handled only 113 tons per train. We may also assume that the extreme difference in the average number of cars per train could not be less than the difference in the average ton miles of through and local freight, or about 28 per cent., which would give the local trains about 15.3 and the through trains about 19.6 cars per train. We will then have, as the units of service for the four combinations—

UNITS OF SERVICE.

| Through. | First. | Second. | Third. | Fourth. |
|---|---|---|---|---|
| Number of tons, | 1,130,047 | 1,130,047 | 1,130,047 | 1,130,047 |
| Train miles, | 1,702,297 | 1,885,241 | 1,702,297 | 1,885,241 |
| Car miles, | 29,284,475 | 32,431,645 | 36,875,095 | 36,875,095 |
| Gross ton miles, | 585,432,765 | 628,122,337 | 663,639,125 | 674,339,153 |
| Local. | | | | |
| Number of tons, | 1,719,794 | 1,719,794 | 1,719,794 | 1,719,794 |
| Train miles, | 2,590,571 | 2,407,627 | 2,590,571 | 2,407,627 |
| Car miles, | 44,565,379 | 41,418,209 | 36,974,759 | 36,974,759 |
| Gross ton miles, | 793,191,119 | 750,501,547 | 714,984,759 | 704,284,731 |

If we take a mean of these units of service of the general tonnage, both through and local, we have—

| | Through. | Local. | Total. |
|---|---|---|---|
| Number of tons, | 1,130,047 | 1,719,794 | 2,849,841 |
| " train miles, | 1,793,769 | 2,499,099 | 4,292,868 |
| " car miles, | 33,919,081 | 39,930,773 | 73,849,854 |
| " gross ton miles, | 637,883,345 | 740,740,539 | 1,378,623,884 |

Taking these units of service, we have as the cost of the through and local tonnage, and the average of both, in cents per ton—

| Through. | Fixed. | Terminal. | Train. | Car. | Gross tonnage. | Total. |
|---|---|---|---|---|---|---|
| First, | 43.58 | 18.23 | 36.44 | 18.80 | 39.95 | 157.00 |
| Second, | 46.76 | 18.23 | 40.36 | 20.82 | 42.87 | 169.04 |
| Third, | 49.41 | 18.23 | 36.44 | 23.68 | 45.29 | 173.11 |
| Fourth, | 50.20 | 18.23 | 40.36 | 23.68 | 46.02 | 178.55 |
| Mean, | 47.49 | 18.23 | 38.40 | 21.78 | 43.53 | 169.43 |

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| Local. | Fixed. | Terminal. | Train. | Car. | Gross tonnage. | Total. |
|---|---|---|---|---|---|---|
| First, | 38.80 | 18.23 | 36.44 | 18.80 | 35.57 | 147.84 |
| Second, | 36.71 | 18.23 | 33.87 | 17.47 | 33.66 | 139.94 |
| Third, | 34.97 | 18.23 | 36.44 | 15.60 | 32.06 | 137.26 |
| Fourth, | 34.45 | 18.23 | 33.87 | 15.60 | 31.58 | 133.69 |
| Mean, | 36.23 | 18.23 | 35.15 | 16.85 | 33.22 | 139.68 |
| Average of both, | 40.70 | 18.23 | 36.44 | 18.80 | 37.31 | 151.48 |

From the foregoing figures we can deduce the following conclusions as to the relative cost per ton of freight hauled on through and local trains, running over the same road, with locomotives of the same capacity.

*A.* If the number of tons of freight handled by each train is the same, and the average load of one of them is reduced during its run, without reduction in the average number of cars per train, the terminal, train and car expenses are the same per ton, notwithstanding the difference in the average haul, and only the fixed and gross tonnage expenses are variable per ton mile.

*B.* If the number of tons handled by each train is the same, and not only the average load, but also the number of cars, is reduced during the run, the terminal and train expenses are the same per ton, notwithstanding the difference in the average haul of the freight, and the fixed, car and gross tonnage expenses are variable per ton mile.

*C.* If the number of tons handled by each train is not the same, whether the number of cars is the same or not, only the terminal expenses are the same per ton, and the fixed, train, car and gross tonnage expenses are variable per ton mile.

These conclusions hold good where a train accumulates its load, as well as where it distributes it, in the course of its progress.

Under the conditions covered by the four combinations of train loads and cars per train, we find invariably a constant or initial cost per ton, which is the same for the longer and the shorter haul, but varies according to the relative number of tons and cars per train, as follows:

| | | | |
|---|---|---|---|
| For the first combination, | 73.47 | cents | per ton. |
| For the second combination, | 18.23 | " | " |
| For the third combination, | 54.67 | " | " |
| For the fourth combination, | 18.23 | " | " |
| Mean of all four combinations, | 41.15 | " | " |

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As the average cost was 151.48 cents per ton, and the average haul 132.3 miles for general tonnage, it is evident that, for each of the constants above stated, and for the mean of all of them, we have as variables per ton mile, and the cost per ton for 132.3 and 189 miles—

| | Constants per ton. | Variables per ton mile. | Cost Per Ton. 132.3 miles. | 189 miles |
|---|---|---|---|---|
| | Cents. | Cents. | Cents. | Cents. |
| First, | 73.47 | 0.5896 | 151.48 | 184.91 |
| Second, | 18.23 | 1.0072 | 151.48 | 208.59 |
| Third, | 54.67 | 0.7317 | 151.48 | 191.53 |
| Fourth, | 18.23 | 1.0072 | 151.48 | 208.59 |
| Mean, | 41.15 | 0.8339 | 151.48 | 198.76 |

When we consider the character of the local freight service, the frequency and regularity with which local freight trains must be run, whether the traffic is heavy or light, steady or fluctuating; the loss of efficiency in train service which results from the short hauls, and the limitation it puts on the use of cars as compared with solid cars of long haul freight, it cannot be deemed unreasonable to regard the train expenses per ton as a constant or initial cost, without regard to the distance the freight is hauled, in which case the third combination of train loads and cars per train would fairly represent the average cost per ton for the through and the local tonnage. It may be, however, that a mean of all four of the above is a nearer approximation to the actual cost.

In order that we may see what the relative cost per ton and per ton mile for different distances would be by these two scales, they are given below as follows:

| Constants. | 54.67 Cents. | | 41.15 Cents. | |
|---|---|---|---|---|
| | Per ton. | Per ton mile. | Per ton. | Per ton mile |
| 10 Miles, | 61.98 | 6.198 | 49.48 | 4.948 |
| 20 " | 69.30 | 3.465 | 57.82 | 2.891 |
| 30 " | 76.62 | 2.554 | 66.16 | 2.205 |
| 40 " | 83.93 | 2.098 | 74.50 | 1.862 |
| 50 " | 91.25 | 1.825 | 82.84 | 1.657 |
| 60 " | 98.57 | 1.643 | 91.18 | 1.519 |
| 70 " | 105.88 | 1.512 | 99.52 | 1.422 |
| 80 " | 113.19 | 1.415 | 107.86 | 1.348 |
| 90 " | 120.51 | 1.339 | 116.20 | 1.291 |
| 100 " | 127.83 | 1.279 | 124.54 | 1.245 |

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| Constants. | 54.67 Cents. | | 41.15 Cents. | |
|---|---|---|---|---|
| | Per ton. | Per ton mile. | Per ton. | Per ton mile. |
| 110 Miles, | 135.14 | 1.229 | 132.87 | 1.207 |
| 120 " | 142.46 | 1.187 | 141.22 | 1.177 |
| 130 " | 149.78 | 1.152 | 149.56 | 1.151 |
| 140 " | 157.10 | 1.122 | 157.90 | 1.128 |
| 150 " | 164.41 | 1.096 | 166.23 | 1.108 |
| 160 " | 171.73 | 1.073 | 174.57 | 1.091 |
| 170 " | 179.05 | 1.053 | 182.91 | 1.076 |
| 180 " | 186.36 | 1.035 | 191.25 | 1.062 |
| 189 " | 192.95 | 1.021 | 198.76 | 1.051 |

The one fact that seems to be established beyond controversy is that, under any and all circumstances, the cost of transporting freight is not in proportion to the distance it is hauled, but greater per ton mile for short than for long distances.

It is not always practicable to charge a reasonable profit on the cost of transportation, for there is a commercial regulation of rates, not only by competition between transportation lines, but by the natural laws of trade, such as supply and demand, and the cost of production as compared with the market value of the products; but the fundamental principle on which tariffs of rates should be framed is that no rate should be made so low as to involve an actual loss in transporting the freight.

Here the question arises as to what latitude may be allowed in the adjustment of rates to meet competition or other commercial requirement, without making unjust discrimination in the distribution of profit on the long and short haul freight.

It is seldom possible to charge as high a percentage of profit on the cost of hauling freight long distances as on the cost of hauling it short distances, without making the rate for long distances disproportionate to the value of the goods; for while a given percentage of profit * on the cost of transporting freight a short distance may be insignificant as compared with the market value of the goods, the same percentage of profit added to the cost of hauling the same goods a long distance may equal, or even exceed, their market value.

* The term "profit," in this and the preceding paragraphs, means earnings in excess of actual outlay for service performed, out of which interest charges and rentals must be paid before there is any real profit.

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*Prima facie,* the cost of any given service includes a relative proportion of all classes of expenses of maintenance and operation, but any freight which pays more than the actual cost of transporting it contributes to the cost of maintaining the highway and other fixed expenses, and cannot, therefore, be said to entail a loss which must be made up by higher charges on other freight; for although it may not contribute its full proportion to fixed expenses, whatever it does contribute is that much less to be obtained from other sources of revenue. For this reason additional traffic is desirable, at rates which could not be considered remunerative if it was not an addition to existing traffic.

Additional freight which does not involve additional train service, but only increases the average loads of trains, can be carried at a profit at rates far below the average cost of transportation, for it increases only terminal, car and gross tonnage expenses, which in the case before us were 50 per cent. of the total cost per ton of general tonnage. If additional freight increased the average train loads without additional car mileage only 38 per cent. of the expenses were increased, but it would not be safe to base regular rates on such exceptional conditions.

In making tariffs of local rates, competition at junction points cannot be disregarded, and it is often the case that such competition influences rates for a considerable distance from the points of contact between transportation lines. In the same manner, rates for short distances from the termini of railways cannot generally be made proportionate to the average cost per ton for very short hauls, and in rural districts wagons may compete with railways for short distances if rates are high enough to pay any profit on the cost of transportation.

It is desirable that we should have a scale for the adjustment of relative rates for local traffic, which is based, as nearly as practicable, on the relative cost of transportation, including both maintenance and operating expenses, but not too high for very short hauls; and the simplest and best one that I have found is to make the rate per ton, or per 100 pounds, proportionate to the *square root of the distance.*

By reference to the diagram at the end of this chapter, it will be seen that the horizontal lines represent distance, and the vertical lines values in cents. In other words, we have a horizontal scale of miles and a vertical scale of cents per ton, which enables us to indicate, by means of diagonal lines, the cost per ton under the

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different conditions above indicated, and also a probable mean of them, indicated as "Talcott's Scale."

The minimum cost at which any freight could have been moved on the road in question was 0.4897 cents per ton mile, for if we exclude fixed and terminal expenses, we have—

| | | |
|---|---|---|
| Train expenses, | 24.19 | cents per train mile. |
| Car expenses, 17.2 car miles @ 0.72559, | 12.48 | " " |
| Gross tonnage expenses, 321.14 @ 0.077125, | 24.77 | " " |
| Cost of moving 125.47 tons of freight one mile, | 61.44 | " " |
| Cost of moving one ton one mile, | 0.4897 | cents. |

It is important to note this, for whatever scale we accept as best representing the relative cost for different distances, the increment for distance cannot properly be less than the cost of movement.

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## CHAPTER XIII.

### Economy in Operation to be Considered in the Location of a Line of Railway.

IT is the duty of the engineer to select the best practicable location from an operating standpoint, and to do this in the field he should have some simple, but effective method of determining the relative merits of such lines as the topographical features of the country admit of.

The gross tonnage of a railway is the total transportation done, expressed in distance and weight, but the actual work done in moving one ton one mile depends upon the alignment and grades; for the resistances encountered on a straight and level line due to friction and speed are increased by curvature, and by gravity on ascending grades.

A simple method of comparing different lines of location is on the basis of the relative power required for the movement of one gross ton mile over them in both directions, and the following formula is a convenient one for this purpose.

$$P = 2000\,E + [(D + L) \times (F + S + C)]$$

D = Distance between termini, in miles.
L = Length of level track, in miles.
E = Sum of the ascents in both directions, in feet.
F = The resistance from friction,
S = The resistance from speed,
C = The resistance from curvature,
} per ton per mile.
P = Total power required per ton mile in foot pounds.

Theoretically L should include only the level track, but practically little or no available assistance is derived from the force of gravity, unless it is sufficient to propel the train without the use of any steam power, and if the force of gravity is beyond the requirements, the surplus is expended in wearing out wheels and brake shoes. For these reasons L practically includes the length of all grades, except such as can be operated one way without any steam power, and, therefore, L may equal D on low grade roads.

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If there is a preponderance of traffic in one direction, as in the case of coal or other minerals where the cars are loaded in one direction only and return empty, the total gravity resistance may be more or less than the sum of the ascents would indicate, in which case we must substitute for the sum of the ascents in both directions an equivalent elevation, to be ascertained as follows:

Let E′ represent the desired equivalent for E; d the difference in elevation between termini; and r the ratio of the lesser gross ton mileage in one direction to that in the other direction, and we have—

$$E' = \frac{E(1+r)+d-dr}{2} \text{ or } \frac{E(1+r)+dr-d}{2} *$$

For example, on the road we have been considering, we have—

$$\begin{aligned} E &= 5929 \text{ feet.} \\ d &= 807 \text{ feet.} \\ r &= 0.8522. \\ dr &= 687.73 \text{ feet.} \end{aligned}$$

Then $5929 \times 1.8522 = 10981.69$,

and $$\frac{10{,}981.69 + 807 - 687.73}{2} = 5{,}550.48 = E'$$

Taking this value of E′ we have for the first formula—

$$\begin{aligned} E' &= 5550.48 \text{ feet.} \\ D &= 189 \text{ miles.} \\ L &= 79 \text{ miles.} \\ (F+S+C) &= 41{,}629 \text{ foot pounds.} \\ 2000 \times 5550.48 &= 11{,}100{,}960 \\ 268 \times 41{,}629 &= 11{,}156{,}572 \end{aligned}$$

P = Power per gross ton mile, 22,257,532

As previously ascertained (in Chap. VI.), 22,288,899

* The first where the preponderance of gross tonnage is in the direction of the greater sum of ascents, and the second where it is in the direction of the lesser sum of ascents.

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The relative resistance opposed to the movement of one ton over the entire length of the line in both directions would be conclusive, but for the actual movement being in train loads, and the train mileage being a factor in the cost of operation, for the larger the train loads the less the cost of hauling them per gross ton mile. In other words, the efficiency of the locomotive as a means of overcoming the resistances should not be ignored.

There are two points of view from which the efficiency of locomotives must be regarded:

*First.* Their capacity to move their trains horizontally.

*Second.* Their capacity to overcome gravity in lifting themselves and their trains over summits.

The tractive power of locomotives being limited by the weight on their driving wheels, their efficiency is greater or less according to the proportion of their total weight, which rests on their driving wheels, as in the case of different types, such as eight-wheel, ten-wheel, mogul, consolidation, and decapod, the relative efficiency of which may be expressed in the ratios of their tractive power to their total weights, in the same order, very nearly as follows, viz., 14, 17, 18, 19 and 20 per cent. These figures also express very nearly the relative gross ton mileage of the maximum trains, locomotives of these types, and of the same total weight, can haul over the same line of railway; that is to say, that when an eight-wheel locomotive of a given weight can haul 1,400 tons, the other types of the same weight should haul 1,700, 1,800, 1,900 and 2,000 tons, provided they are properly proportioned as to grate and heating surface, cylinder power, etc.

The train resistance on straight and level track, at a uniform speed, is constant, and moderate curvature makes but little addition thereto; but when grades are encountered, the resistance due to gravity must also be overcome, and the efficiency of a locomotive in hauling loads horizontally and in overcoming elevations is not the same, for the maximum of useful effect produced by a locomotive in overcoming elevations is not obtained by lengthening the line to secure the lowest rate of ascent, as will be shown hereafter. (See Appendix.)

The prevailing maximum grade, or rate of ascent, limits the capacity of a single locomotive, and fixes the maximum weight of trains it can haul over the line, and while all trains will not be of the maximum weight, the average train is gen-

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erally in proportion to the maximum, and upon the average weight of trains will depend the number of trains required to move the total tonnage, and consequently the train mileage.

The train expenses, as shown in Chapter IV., were 23.99 per cent. of the total cost of operating, or say 24 per cent., and this proportion only of the cost of operating would have been increased by reducing the average weight of trains in consequence of heavier grades. Unless, therefore, the anticipated traffic is extraordinarily heavy, it is best to adopt the line of least resistance per ton mile, provided its maximum grades are not excessive.

The first question in reference to maximum grades which the engineer should decide is, to what extent other considerations should be disregarded in order to secure the lowest maximum grade; and the next question is, to what extent the maximum grade may be used.

The shorter the distance in which the required elevation is attained, the more persistent the rate of ascent, and the less the resistance per ton mile, and consequently the less the power required to reach the summit in the same time; but on the other hand, the lower the maximum rate of ascent, the more load a locomotive can haul over it, and this generally means the more it will haul over the whole length of the road, the exception being where assistant power or "Helpers" are used on exceptional grades for short distances. For instance, as between grades of one, and one and a quarter per cent. the relative resistances are for one foot elevation.

ON A GRADE OF ONE PER CENT.:

| | | |
|---|---|---|
| 100 feet at 8.33 lbs. per foot, equal to, ..... | 833 | foot pounds. |
| 2000 pounds raised one foot, equal to, ..... | 2000 | " " |
| Total resistance, ..... | 2833 | " " |

ON A GRADE OF ONE AND A QUARTER PER CENT.:

| | | |
|---|---|---|
| 80 feet at 8.33 pounds per foot, ..... | 666 | foot pounds. |
| 2000 lbs. raised one foot, ..... | 2000 | " " |
| Total resistance, ..... | 2666 | " " |

This shows 5.9 per cent. less resistance to attain the same elevation, and consequently 5.9 per cent. less power is required to do the work in the same time with

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the grade of one and a quarter per cent. Besides this, the distance is 25 per cent. less, and this means a saving of 25 per cent. in the length of road to be maintained, and in train and car mileage, for the length of the grades, while one locomotive should haul 17.7 per cent. more load over a one per cent. grade, which would make a reduction of 15.0 per cent. in the train mileage of the road, if the traffic was handled in maximum train loads. See Note at end of this Chapter.

If, therefore, a saving of 5.9 per cent. in motive power, and of 25 per cent. in train mileage, car mileage, and maintenance of roadway, on so much of the road as is included in the length of the maximum grades of one and a quarter per cent., equals the saving of 15.0 per cent. in train mileage on the whole road, with maximum grades of one per cent., the advantage in favor of one or the other will depend upon the relative cost of construction.

For the reasons stated above, exceptionally high grades at a few points are very objectionable, as are also descending grades, which sacrifice elevation that must be regained by an addition to the sum of the ascents, and therefore to the total resistance from gravity.

When a certain maximum grade is ascertained to be inevitable as a prevailing feature in the most desirable line, there can be no reasonable objection to its use on such part of the line as must necessarily be operated by the locomotives to be provided for such maximum grades, even though lower grades are practicable, provided frequent and sudden breaks in the grades which are inconsistent with general uniformity in ascents are avoided.

On long ascending grades the introduction of occasional level stretches may be advisable, to give the locomotive an opportunity to increase its steam pressure, and the equation of grades for curvature is necessary to secure uniformity in train resistance.

Financial considerations often make it impracticable to adhere closely to the most favorable location, and in such cases the engineer should endeavor to economize in construction with as little deviation from the proper alignment as possible, preferring to sacrifice the best features of his profile rather than adopt an alignment which admits of no subsequent improvement in its maximum grades, or reduction in the sum of its ascents.

No greater mistake can be made at the inception of an enterprise than restriction in expenditure to secure information necessary to mature plans for its

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success, and such mistakes are too often made in the surveys for a projected railway. It is better to incur the cost of several experimental lines than to fail to secure the best; but still better to carefully reconnoitre the country, and select a favorable route, before incurring the expense of actual surveys; for money saved in preliminary surveys can be used to great advantage in perfecting the final location.

### Useful Effect of the Force of Gravity.

In making close comparisons of two or more lines, it is necessary to consider the useful effect of gravity on descending grades, an illustration of which has been given in Chapter VI. The greater the proportion of gravity that can be utilized to move trains at normal speed on descending grades, and the less consumed in wearing out wheels and brake shoes, the greater will be the ratio of useful effect of the power derived from the locomotive.

Note.—On the road we have been considering, the difference in cost of 500 ton trains of 20 cars, and 588 ton trains of 24 cars, would have been approximately:

| | Per Train Mile. | | | |
|---|---|---|---|---|
| | 500 Ton Trains. | | 588 Ton Trains. | |
| Train expenses, | 24.19 | cents. | 24.19 | cents. |
| Car expenses, | 14.51 | " | 17.41 | " |
| Fuel and water, | 20.31 | " | 23.89 | " |
| Maintenance of track, | 7.18 | " | 8.45 | " |
| Total, | 66.19 | " | 73.94 | " |

588 ton trains, ..... 85 train miles @ 73.94 = $62.85
500 ton trains, ..... 100 train miles @ 66.19 = 66.19

Saving in cost for the same tonnage, ..... $ 3.34 or 5.05 per cent.

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## TABLE OF TRAIN RESISTANCES PER GROSS TON MILE, DUE TO FRICTION SPEED AND CURVATURE AT DIFFERENT DEGREES OF CURVATURE PER MILE.

Values of (F + S + C) per gross ton mile.

| Degrees of Curvature per Mile. | Speed in Miles Per Hour. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
| 0 ..... | 34.750 | 38.687 | 43.960 | 50.867 | 59.312 | 69.287 | 80.800 | 93.847 | 108.430 |
| 5 ..... | 35.000 | 38.937 | 44.210 | 51.117 | 59.562 | 69.537 | 81.050 | 94.097 | 108.680 |
| 10 ..... | 35.250 | 39.187 | 44.460 | 51.367 | 59.812 | 69.787 | 81.300 | 94.347 | 108.930 |
| 15 ..... | 35.500 | 39.437 | 44.710 | 51.617 | 60.062 | 70.037 | 81.550 | 94.597 | 109.180 |
| 20 ..... | 35.750 | 39.687 | 44.960 | 51.867 | 60.312 | 70.287 | 81.800 | 94.847 | 109.430 |
| 25 ..... | 36.000 | 39.937 | 45.210 | 52.117 | 60.562 | 70.537 | 82.050 | 95.097 | 109.680 |
| 30 ..... | 36.250 | 40.187 | 45.460 | 52.367 | 60.812 | 70.787 | 82.300 | 95.347 | 109.930 |
| 35 ..... | 36.500 | 40.437 | 45.710 | 52.617 | 61.062 | 71.037 | 82.550 | 95.597 | 110.180 |
| 40 ..... | 36.750 | 40.687 | 45.960 | 52.867 | 61.312 | 71.287 | 82.800 | 95.847 | 110.430 |
| 45 ..... | 37.000 | 40.937 | 46.210 | 53.117 | 61.562 | 71.537 | 83.050 | 96.097 | 110.680 |
| 50 ..... | 37.250 | 41.187 | 46.460 | 53.367 | 61.812 | 71.787 | 83.300 | 96.347 | 110.930 |
| 55 ..... | 37.500 | 41.437 | 46.710 | 53.617 | 62.062 | 72.037 | 83.550 | 96.597 | 111.180 |
| 60 ..... | 37.750 | 41.687 | 46.960 | 53.867 | 62.312 | 72.287 | 83.800 | 96.847 | 111.430 |
| 65 ..... | 38.000 | 41.937 | 47.210 | 54.117 | 62.562 | 72.537 | 84.050 | 97.097 | 111.680 |
| 70 ..... | 38.250 | 42.187 | 47.470 | 54.367 | 62.812 | 72.787 | 84.300 | 97.347 | 111.930 |
| 75 ..... | 38.500 | 42.437 | 47.710 | 54.617 | 63.062 | 73.037 | 84.550 | 97.597 | 112.180 |
| 80 ..... | 38.750 | 42.687 | 47.960 | 54.867 | 63.312 | 73.287 | 84.800 | 97.847 | 112.430 |
| 85 ..... | 39.000 | 42.937 | 48.210 | 55.117 | 63.562 | 73.537 | 85.050 | 98.097 | 112.680 |
| 90 ..... | 39.250 | 43.187 | 48.460 | 55.367 | 63.812 | 73.787 | 85.300 | 98.347 | 112.930 |
| 95 ..... | 39.500 | 43.437 | 48.710 | 55.617 | 64.062 | 74.037 | 85.550 | 98.597 | 113.180 |
| 100 ..... | 39.750 | 43.687 | 48.960 | 55.867 | 64.312 | 74.287 | 85.800 | 98.847 | 113.430 |

Note.—The above table gives the average resistance due to friction, speed and curvature, with sufficient accuracy for practical purposes, where there are no exceptionally hard curves.

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# APPENDIX.

The following is the formula used by Capt. Andrew Talcott, of the United States Corps of Engineers (in 1858) to find the useful effect of locomotives on grades.

To Find the Useful Effect of Engines on Grades.

E, Weight of engine in pounds, all on driving wheels.
F, Friction of one ton of load.*
P, Ratio of adhesion.
P E, Adhesion of engine.
L, Weight of load in pounds.
S, Sine of the angle of grade, or slope of the road.

Whatever greater power of traction the engine may have than its own friction, is limited by the adhesion of the wheels to the rails. The force of gravity will be $S (E + L)$, and the friction of the load is $\frac{L F}{2240}$. Consequently the engine cannot move the load when $(E + L) S + \frac{L F}{2240} = P E$ [I.], or when $L = \frac{2240 (P E - E S)}{2240 S + F}$ [II.] the power and resistance are exactly balanced.

The useful effect of the engine will be as $L \times S$, or the weight of the load, and the height overcome in an unit of time, and this will be the greatest when

$$S = \frac{-F}{2240} + \sqrt{\frac{P F}{2240} + \frac{F^2}{(2240)^2}}$$

By substituting the ratio of adhesion to the weight of engine, in the above equation, the value of "S" for any ratio of adhesion may be obtained.

| | |
|---|---|
| For P = 18 per cent., | S = 0.02203. |
| " P = 20 " " | S = 0.02339. |
| " P = 22 " " | S = 0.02469. |
| " P = 24 " " | S = 0.02592. |
| " P = 26 " " | S = 0.02711. |

* Estimated at 8 pounds per ton of 2,240 pounds.

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